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ATMOSPHERIC VARIATIONS IN AND NEAR FULDA

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This report contains a considerable amount of information about atmospheric conditions in and near Fulda. Numerous contingency tables for pairs of meteorological variables include statistics which have not previously been published. Results of an extensive literature search are also summarized. Visibility, clouds, precipitation, temperature, dew point, and winds are among the topics which are discussed in the report.

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I. INTRODUCTION

From time to time the RD&E Center's Research Directorate receives inquiries from the Project Offices and Agencies within the Missile Command about climatic conditions in the Fulda area. Since this information is scattered in various texts and in a variety of other unpublished data, we have compiled this material into one report.

Fulda is in the Federal Republic of Germany (West Germany) near the border with the German Democratic Republic (East Germany). Weather measurements for Fulda are taken at station 105445 at 50°32'N and 009°38'E at the American Armed Forces Base at Fulda. Regular observations are made from 0500 Greenwich mean time (GMT) (0600 Central European Time (CET)) to 1600 GMT (1700 CET) during the week. Observations are made sporadically during the night and on weekends and holidays.

Fulda is located along the Fulda river in a mountainous region of Hesse approximately 80 km northeast of Frankfurt am Main. The elevation of the meteorological observing station is 1000 ft (305 m). Because of the complicated topography in the region, similarity between nearby stations does not have a straightforward dependence upon distance alone. The degree of similarity between sites depends on station elevation, relative height with respect to the surroundings, and proximity to rivers. Urbanization and other anthropogenic effects may also be very important. Figure 1 shows the locations of the stations discussed in this report.

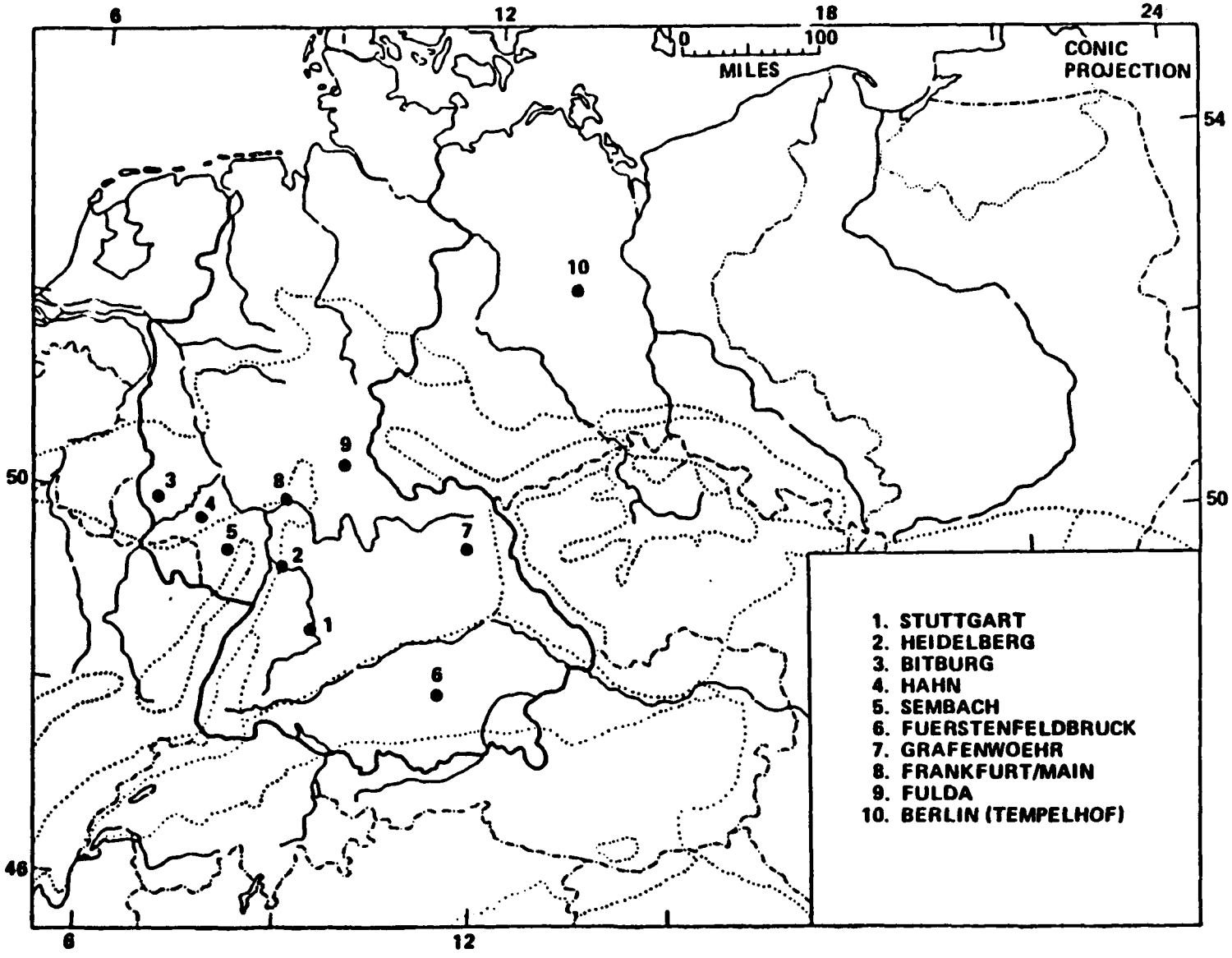


Figure 1. Location of stations.

II. HYDROMETEORS THAT REDUCE VISIBILITY

This section covers problems that reduce visibility. Scattering in the atmosphere is the main cause of reduced visibility. Molecular absorption is rarely large enough to be a problem at any visible wavelength [1]. Fog droplets are the most bothersome scatterers at visible wavelengths; however, there are other hydrometeors and pollution that contribute to reduced visibility.

The following paragraphs deal with these hydrometeors. Also of possible interest are descriptions of some standard environmental conditions published by Humphrey and Pepper [2]. These conditions comprise a summary of seven stations in the Fulda area. It must be reiterated from the introduction that these average environmental conditions in the Fulda area may not represent the realistic climatic conditions at Fulda due to the complex terrain conditions in the Fulda area. Thus, the climatic conditions at Fulda may deviate considerally from the averages assembled by Humphrey and Pepper [2]

A. Fog

1. Background

By international agreement, fog exists when an aggregate of water droplets (or small ice particles) suspended in the atmosphere reduces visibility below 1 km [3].

Frequency of occurrence of German fogs is strongly influenced by orographic features in the area surrounding an observational site [4]. River valleys usually have large amounts of fog. Very low visibilities are much more frequent on the windward side of mountains than in the lee of mountains. The longer the wind direction is constant, the worse the visibility is on the windward side [5]. The contrast between visibilities on windward and lee sides of mountains is largest when radiation fog envelops most of a region.

Observation sites at high elevations often have high fog frequencies because they are up among the clouds. Wasserkuppe is a mountainous station approximately 18 km from Fulda. According to a publication in 1956 [4], an observation site at 950 m at Wasserkuppe has fog on an average of 273 days during the year. More recent statistics, published in 1983 [2] in graphical form, show that 38 percent of visibilities for all hours of the year are less than 1 km at an observation site at 921 m at Wasserkuppe.

An investigation of 207 stations in the Federal Republic of Germany for the 30-year period 1951-1980 reveals a trend in the frequency of days with fog at most stations [6]. At a 99-percent confidence level with a t-test, 56 stations showed no trend, 112 stations showed a negative trend, and 39 had an increasing number of days with fog during the 30-year period. Kassel, a station along the Fulda river about 80 km north of Fulda, showed a trend of decreasing frequency of days with fog at a confidence level about 99.9 percent. Increasing frequency of fog was observed primarily at mountainous stations. No mountainous station near Fulda was specifically mentioned as having an increase in fog.

The difference between trends at mountainous stations and at lower stations is consistent with differences in weather situations associated with fog at different elevations. Clear weather with an extensive high pressure system often produces strong nocturnal temperature inversions and fog at low levels while stations above the inversion have no fog. Unstable air associated with low pressure often produces clouds which are experienced as fog at mountainous stations while lower land has no fog.

Schulze-Neuhoff [7] examined two days when a high pressure system dominated central and southern Germany. Fog was very widespread in the early morning hours and persisted until midday in a few areas. Extremely detailed maps were produced with data from 420 stations. A significant fact for this report is that at 0600 GMT, 30 October 1975, the Vogelsberg mountain near Fulda was free of fog while low land surrounding the mountain in all directions was foggy. Furthermore, at 2000 GMT, 31 October 1975, a much larger area was free of fog, but the Fulda river valley contained fog. The wind shifted from southwest to southeast during Schulze-Neuhoff's study. This shift changed the location of lowest visibility relative to mountainous terrain. Windward sides of mountains definitely had more fog.

Another investigator [8] has shown that visibility is a function of wind direction in long-term means in Germany. At Frankfurt am Main lowest mean visibilities were associated with southeasterly winds and highest visibilities were associated with northeasterly winds. This study, published in 1929, used an outdated and very nonlinear scale therefore it is not possible to estimate the magnitude of the difference reliably.

Finally, it should be noted that fog water may be acidic [9]. Measurements from November 1982 through March 1983 at Bad Steben in Northern Bavaria were closer to Fulda than any others that we could find. The values of pH in fog were from 3.1 to 4.3 initially. It was shown that as drops evaporated on plants, concentrations of impurities increased, and pH values could become less than 2.0.

2. Frequency and Duration

Of most interest may be the occurrence of visibility $\leq$ 1 km (fog). Table 1 exhibits the percentage frequencies of visibility for Fulda at 8 hours of the day for four seasons during 1968-1976. Fog is broken down into three categories: under 0.2 km, from 0.2 to 0.5 km, and 0.5 to 1 km. The results are in line with expectation, i.e., the highest occurrence of fog is in fall in the morning hours (local time). The percentage figures of roughly 25 percent may be a surprise; however, considering the terrain conditions these numbers are not unreasonable. Since night hour observations have not been made, or comprise only a short time period, estimates have been carefully made by studying the surrounding stations and have been substituted in the table.

Table 2 lists the cumulative frequency distribution derived from Table 1.

TABLE 1. Frequency Distribution of Visibility for Fulda (% of Occurrence)

Season	Hour*	<0.2	0.2-0.5	0.5-1	1-2	2-4	4-10	10-20	>20 km
Winter	01	.0	.4	3.1	1.8	9.2	40.8	36.7	7.9
	04	1.5	1.8	2.2	7.5	17.3	33.0	22.9	13.8
	07	3.5	2.0	2.9	10.2	17.7	31.4	20.5	11.7
	10	3.0	1.9	4.4	12.5	20.3	26.7	19.6	11.5
	13	.8	1.4	2.5	9.2	17.9	31.0	20.9	16.3
	16	.8	.9	2.1	8.3	16.3	31.6	21.2	18.8
	19	1.0	1.0	1.5	7.9	19.3	28.3	22.1	19.0
	22	0.4	.0	1.3	3.0	10.0	36.8	39.4	9.1
Average		1.8	1.2	2.5	7.5	15.8	32.3	25.4	13.5
Spring	01	.5	.1	.8	1.1	2.3	16.8	48.1	30.3
	04	3.2	1.1	1.5	5.2	8.7	25.4	26.3	28.6
	07	4.9	1.7	2.1	6.3	13.3	26.1	25.0	20.6
	10	1.1	.5	.9	3.7	10.6	25.8	27.9	29.5
	13	.0	.0	.1	1.5	4.3	20.5	28.7	45.0
	16	.0	.0	.2	.7	3.0	15.8	27.1	53.3
	19	.1	.0	.1	1.2	3.7	13.6	25.3	56.0
	22	.0	.0	.0	.3	1.7	13.9	46.5	37.6
Average		1.2	0.4	0.7	2.5	6.0	19.7	31.9	37.6
Summer	01	1.7	.3	.2	.8	1.5	17.3	36.7	41.5
	04	5.7	2.0	1.9	6.6	8.0	26.4	23.8	25.5
	07	5.4	1.9	2.2	4.8	11.2	24.6	26.1	23.8
	10	.1	.4	.5	1.0	4.5	21.2	31.6	40.8
	13	.0	.0	.0	.0	.9	9.3	28.0	61.8
	16	.0	.0	.0	.1	.5	6.0	24.1	69.3
	19	.0	.0	.0	.1	1.0	7.2	23.7	68.0
	22	.0	.0	.2	.2	.5	9.9	39.9	49.4
Average		1.6	.6	.6	1.7	3.5	15.3	29.2	47.5
Fall	01	8.9	.6	3.0	3.8	5.6	29.7	28.3	20.2
	04	13.7	6.5	3.4	5.7	10.2	24.9	17.8	17.8
	07	19.2	3.9	3.8	5.4	10.2	23.9	17.6	16.0
	10	8.4	2.6	3.2	5.6	13.7	25.1	22.8	18.7
	13	1.2	0.3	1.1	2.3	8.7	26.9	26.1	33.4
	16	1.0	0.5	0.9	2.1	6.6	22.8	26.2	39.9
	19	1.8	0.8	0.6	2.5	8.2	23.9	23.4	38.9
	22	3.7	0.9	2.2	3.0	6.2	25.6	32.6	25.7
Average		7.2	2.0	2.3	3.8	8.7	25.3	24.4	26.3

*Local Time.

TABLE 2. Cumulative Frequency Distribution of Visibility for Fulda (% of Occurrence)

Season	Hour*	0.2	0.5	1	2	4	10	20 km	>20 km
Winter	01	.0	.4	3.5	5.3	14.5	55.3	92.0	99.9
	04	1.5	3.3	5.5	13.0	30.3	63.3	86.2	100.0
	07	3.5	5.5	8.4	18.6	36.3	67.7	88.2	99.9
	10	3.0	4.9	9.3	21.8	42.1	68.8	88.4	99.9
	13	.8	2.2	4.7	13.9	31.8	62.8	83.7	100.0
	16	.8	1.7	3.8	12.1	28.4	60.0	81.2	100.0
	19	1.0	2.0	3.5	11.4	30.7	59.0	81.1	100.1
	22	0.4	0.4	1.7	4.7	14.7	51.5	90.9	100.0
	Average	1.8	3.0	5.5	13.0	28.8	61.1	86.5	100.0
Spring	01	.5	.6	1.4	2.5	4.8	21.6	69.7	100.0
	04	3.2	4.3	5.8	11.0	19.7	45.1	71.4	100.0
	07	4.9	6.6	8.7	15.0	28.3	54.4	79.4	100.0
	10	1.1	1.6	2.5	6.2	16.8	42.6	70.5	100.0
	13	.0	.0	.1	1.6	5.9	26.4	55.1	100.0
	16	.0	.0	.2	.9	3.9	19.7	46.8	100.1
	19	.1	.1	.2	1.4	5.1	18.7	44.0	100.0
	22	.0	.0	.0	.3	2.0	15.9	62.4	100.0
	Average	1.2	1.6	2.3	4.8	10.8	30.5	62.4	100.0
Summer	01	1.7	2.0	2.2	3.0	4.5	21.8	58.5	100.0
	04	5.7	7.7	9.6	16.2	24.2	50.6	74.4	99.9
	07	5.4	7.3	9.5	14.3	25.5	50.1	76.2	100.0
	10	0.1	0.5	1.0	2.0	6.5	27.7	59.3	100.1
	13	.0	0.0	.0	.0	.9	10.2	38.2	100.0
	16	.0	0.0	.0	.1	.6	6.6	30.7	100.0
	19	.0	0.0	.0	.1	1.1	8.3	32.0	100.0
	22	.0	0.0	.2	.2	.7	10.6	50.5	99.9
	Average	1.6	2.2	2.8	4.5	8.0	23.3	52.5	100.0
Fall	01	8.9	9.5	12.5	16.3	21.9	51.6	79.9	100.1
	04	13.7	20.2	23.6	29.3	39.5	64.4	82.2	100.0
	07	19.2	28.1	26.9	32.3	42.5	66.4	84.0	100.0
	10	8.4	11.0	14.2	19.8	33.5	58.6	81.4	100.1
	13	1.2	1.5	2.6	4.9	13.6	40.5	66.6	100.0
	16	1.0	1.5	2.4	4.5	11.1	33.9	60.1	100.0
	19	1.8	2.6	3.2	5.7	13.9	37.8	61.2	100.1
	22	3.7	4.6	6.8	9.8	16.0	41.6	74.2	99.9
	Average	7.2	9.2	11.5	15.3	24.0	49.3	73.7	100.0

*Local Time.

For comparison, the frequency distributions for Frankfurt and Hahn (see Fig. 1) have been included in this report (Tables 3 and 4) although only for the fall and winter seasons. The winter season is listed first in order to compare with the previous tables where winter is listed first.

Since night observations are mostly missing for Fulda, the duration of fog cannot be readily derived. Effort to estimate durations is presented in Paragraph C, "Adverse Weather." Thus, as a guidance the duration of fog for Frankfurt (1966-1976) is included in Table 5. Note that the 16 classes represent 3-hourly durations, e.g., fog beginning during 16 to 19 hours at Frankfurt in the fall season lasted 48 hours in 12 percent of the cases.

The duration of fog for Frankfurt (1966-1976), in days, is presented in Table 6. The reader is cautioned about any misinterpretation. The figures in Table 6 reflect only that on the next day or the following days, fog was present at the same hour without consideration whether fog was interrupted or continuous during the interim time.

As a supplement, Table 7 displays the occurrence of fog and mist (i.e., visibility 1-2 km) for four individual months at eight given hours for Frankfurt (Kays, et al., p. 43 [10]). October and January have more fog and mist than April and July throughout the day. At 1200 GMT and 1500 GMT, January has nearly twice as much fog and mist as October. At 0000 GMT, 0300 GMT, and 0600 GMT, fog and mist are much more frequent in October than in January. At 0900 GMT, 1800 GMT, and 2100 GMT, visibility below 2 km has about the same probability in January and October at Frankfurt.

TABLE 3. Cumulative Frequency Distribution (%) of Visibility

Season	Hour*	0.2	0.5	1	2	4	10	20	>20 km
A. Frankfurt									
Winter	01	2.1	4.7	7.0	14.2	28.4	58.6	89.0	100.0
	04	2.6	5.2	7.7	14.9	28.8	59.1	89.7	100.1
	07	2.7	5.9	9.4	20.6	37.7	64.7	90.5	100.0
	10	1.8	4.7	9.2	23.3	41.7	68.2	89.1	100.0
	13	0.3	1.7	6.2	17.5	32.4	59.1	84.3	99.9
	16	1.1	2.7	6.6	16.2	31.6	57.5	83.0	99.8
	19	1.8	3.2	5.4	12.6	27.2	58.2	87.0	100.0
	22	1.8	3.9	6.1	13.4	28.2	58.2	88.2	100.0
	Average	1.8	4.0	7.2	16.6	32.0	60.4	87.6	100.0
Fall	01	2.3	4.7	6.7	12.1	26.4	55.9	88.8	99.9
	04	3.7	7.6	10.3	17.3	33.1	62.3	90.8	99.9
	07	4.3	9.3	13.6	25.3	43.4	72.0	92.2	100.0
	10	1.1	3.5	6.5	15.5	28.5	59.6	87.3	100.0
	13	0.1	0.5	2.0	7.1	15.5	40.3	74.4	100.0
	16	0.3	0.7	1.9	6.9	14.9	37.3	69.3	100.1
	19	0.8	1.6	2.6	7.1	16.5	42.4	77.2	100.0
	22	1.8	3.2	4.9	10.1	21.0	50.9	85.0	100.2
	Average	1.8	3.9	6.1	12.7	24.9	52.6	83.1	100.0
B. Hahn									
Winter	01	9.1	12.9	17.1	24.4	38.4	67.7	93.9	99.9
	04	8.5	13.3	17.7	25.7	40.9	70.3	94.9	100.0
	07	9.3	13.7	19.4	28.9	43.9	71.3	95.1	100.0
	10	8.1	11.7	18.1	28.5	41.6	67.7	94.0	99.9
	13	6.6	9.6	15.0	24.1	35.9	61.9	91.6	100.0
	16	7.4	9.9	14.5	23.5	36.9	63.2	92.1	100.0
	19	6.0	9.3	13.8	21.0	36.5	65.8	93.4	100.0
	22	7.0	10.5	14.0	21.3	35.8	65.5	94.0	100.0
	Average	7.8	11.4	16.2	24.7	38.8	66.7	93.7	100.0
Fall	01	5.9	8.4	12.1	18.9	29.5	54.8	91.0	100.1
	04	8.6	12.3	17.1	24.6	35.8	61.0	92.4	100.1
	07	11.0	14.8	19.5	27.0	37.2	60.9	91.5	100.1
	10	5.2	7.9	10.8	17.3	25.5	49.2	87.0	100.0
	13	2.6	4.2	5.9	10.6	17.1	37.9	81.4	99.9
	16	3.2	4.9	7.0	11.1	18.7	38.9	81.6	100.0
	19	3.4	5.3	7.6	12.6	22.0	45.6	87.5	100.0
	22	4.6	6.7	9.3	14.2	24.1	48.0	88.6	100.1
	Average	5.5	8.0	11.1	17.0	26.2	49.5	87.6	100.0

*Local Time.

TABLE 4. Frequency Distribution of Visibility (%)

Season	Hour*	<0.2	0.2-0.5	0.5-1	1-2	2-4	4-10	10-20	>20 km
A. Frankfurt									
Winter	01	2.1	2.6	2.3	7.2	14.1	30.2	30.4	11.0
	04	2.6	2.6	2.5	7.2	13.9	30.3	30.6	10.4
	07	2.7	3.2	3.5	11.2	17.1	27.0	25.8	9.5
	10	1.8	2.9	4.5	14.1	18.4	26.5	20.9	10.9
	13	0.3	1.4	4.5	11.3	14.9	26.7	25.2	15.6
	16	1.1	1.6	3.9	9.6	15.4	25.9	25.5	16.8
	19	1.8	1.4	2.2	7.2	14.6	31.0	28.8	13.0
	22	1.8	2.1	2.2	7.3	14.8	30.0	30.0	11.8
	Average	1.8	2.2	3.2	9.4	15.4	28.4	27.2	12.4
Fall	01	2.3	2.4	2.0	5.4	14.3	29.5	32.9	11.1
	04	3.7	3.9	2.7	7.0	15.8	29.2	28.5	9.1
	07	4.3	5.0	4.3	11.7	18.1	28.6	20.2	7.8
	10	1.1	2.4	3.0	9.0	13.0	31.1	27.7	12.7
	13	0.1	0.4	1.5	5.1	8.4	24.8	34.1	25.6
	16	0.3	0.4	1.2	5.0	8.0	22.4	32.0	30.8
	19	0.8	0.8	1.0	4.5	9.4	25.9	34.8	22.8
	22	1.8	1.4	1.7	5.2	10.9	29.9	34.1	15.2
	Average	1.8	2.1	2.2	6.6	12.2	27.7	30.5	16.9
B. Hahn									
Winter	01	9.1	3.8	4.2	7.3	14.0	29.3	26.2	6.0
	04	8.5	4.8	4.4	8.0	15.2	29.4	24.6	5.1
	07	9.3	4.4	5.7	9.5	15.0	27.4	23.8	4.9
	10	8.1	3.6	6.4	10.4	13.1	26.1	26.3	5.9
	13	6.6	3.0	5.4	9.1	11.8	26.0	29.7	8.4
	16	7.4	2.5	4.6	9.0	13.4	26.3	28.9	7.9
	19	6.0	3.3	4.5	7.2	15.5	29.3	27.6	6.6
	22	7.0	3.5	3.5	7.3	14.5	29.7	28.5	6.0
	Average	7.8	3.6	4.8	8.5	14.1	27.9	27.0	6.3
Fall	01	5.9	2.5	3.7	6.8	10.6	25.3	36.2	9.1
	04	8.6	3.7	4.8	7.5	11.2	25.2	31.4	7.7
	07	11.0	3.8	4.7	7.5	10.2	23.7	30.6	8.6
	10	5.2	2.7	2.9	6.5	8.2	23.7	37.8	13.0
	13	2.6	1.6	1.7	4.7	6.5	20.8	43.4	18.5
	16	3.2	1.7	2.1	4.1	7.6	20.2	42.7	18.4
	19	3.4	1.9	2.3	5.0	9.4	23.6	41.9	12.5
	22	4.6	2.1	2.6	4.9	9.9	23.9	40.6	11.5
	Average	5.5	2.5	3.1	5.9	9.2	23.3	38.1	12.4

*Local Time.

TABLE 5. Duration of Visibility $\leq$ 1 km for Frankfurt (Cumulative %), 3-Hourly Classes

Longer than x hours																	
Begin*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	N
Fall																	
00-03	71	60	55	50	43	37	26	20	14	9.2	6.1	4.9	4.3	3.7	3.7	3.1	163
04-07	71	49	35	23	14	7.2	3.3	3.0	2.6	2.6	2.3	2.3	1.9	1.9	1.5	1.5	265
08-11	36	18	7.7	3.8	1.3	1.3	1.3	1.3	0								78
12-15	67	44	36	19	14	14	14	14	8.3	8.3	8.3	8.3	8.3	5.6	5.6	5.6	36
16-19	62	54	46	43	42	38	32	32	32	29	25	22	20	17	17	12	69
20-23	73	58	50	42	41	39	36	30	28	26	25	16	10	6.8	5.1	2.5	118
Total	66	50	40	32	26	22	16	14	12	10	8.8	6.9	5.5	4.4	4.0	2.9%	
Winter																	
00-03	70	53	44	35	35	31	29	21	17	13	11	9.7	8.8	8.0	8.0	7.1	113
04-07	70	49	40	35	29	23	17	16	13	12	11	9.6	7.3	6.6	5.9	5.9	136
08-11	56	36	25	17	12	9.9	8.8	7.6	5.3	4.7	4.7	4.0	4.0	4.0	2.9	2.9	171
12-15	67	49	32	22	18	12	12	12	9.5	7.6	7.6	7.6	7.6	6.7	5.7	5.7	105
16-19	54	40	34	31	23	20	15	14	12	8.4	8.4	8.4	8.4	8.4	8.4	8.4	95
20-23	74	55	46	41	33	28	27	23	21	19	18	14	10	8.3	4.2	3.1	96
Total	64	46	36	29	24	20	17	15	12	10	9.5	8.4	7.4	6.7	5.6	5.3	

*Greenwich Time

TABLE 6. Duration of Days with Visibility ≤ 1 km for Frankfurt (Cumulative %)

Longer than x days												
Begin*	1	2	3	4	5	6	7	8	9	10	11	N
Fall												
00-03	22	9.3	5.7	3.0	1.5	0						473
04-07	25	9.0	4.1	2.4	0.8	0.5	0.3	0				781
08-11	25	10	4.2	1.6	1.0	0.8	0.6	0.2	0.2	0.2	0.2	495
12-15	16	6.3	1.9	1.9	1.9	1.9	0.6	0				159
16-19	16	5.0	3.3	2.8	1.7	1.1	1.1	0				180
20-23	23	9.0	2.7	2.0	0.7	0						301
Total	23	8.7	4.0	2.2	1.0	0.5	0.3	0.2	0.1	0.0	0.0	2389
Winter												
00-03	22	5.6	1.2	0								432
04	22	6.1	1.6	0.6	0.6	0						493
08	28	7.9	2.0	1.0	1.0	0						530
12	20	6.3	0.2	0.2	0							396
16	26	4.9	0.9	0.9	0.3	0						329
20	26	7.3	1.7	1.2	0							343
Total	23	6.2	1.3	.6	.3							2583

*Greenwich Time

TABLE 7. Percent Frequency of Fog and Mist (Frankfurt)

Month*	00	03	06	09	12	15	18	21
January	18.3	19.5	20.4	25.0	16.0	13.1	16.5	18.1
April	5.0	9.3	13.0	3.1	0.4	0.1	0.5	1.1
July	5.1	12.3	15.6	1.4	0.6	0.2	0.7	1.7
October	24.5	27.5	31.3	24.2	8.2	6.3	15.6	20.0

*Period of Record: January 1966 - March 1977. Hours are in Greenwich Mean Time.

B. Clouds and Ceilings

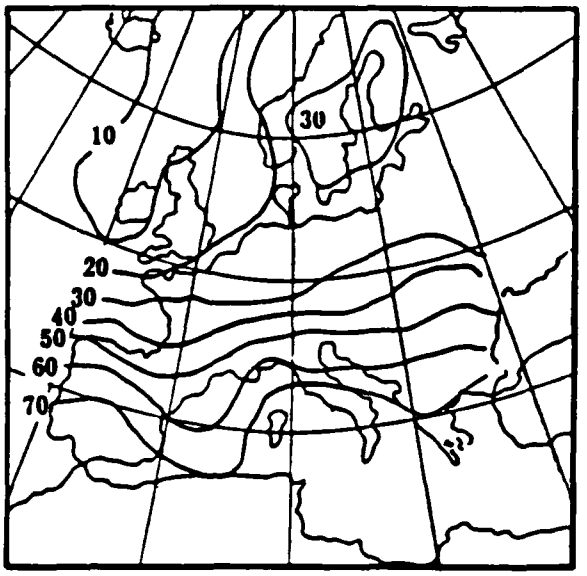
Clouds and ceilings are treated in this paragraph as a single element. The simultaneous occurrence with classes of visibility is discussed in the paragraphs below and in Paragraph C.

Figure 2 shows the frequency of occurrence of specified groups of sky cover for Europe in July and January. This figure was also adopted from Kays et al., p. 37 [10]. Although the conditions at Fulda can hardly be recognized, we have included this graph to provide the reader with a comparison of the conditions at Fulda and conditions on a large scale in the same geographical region.

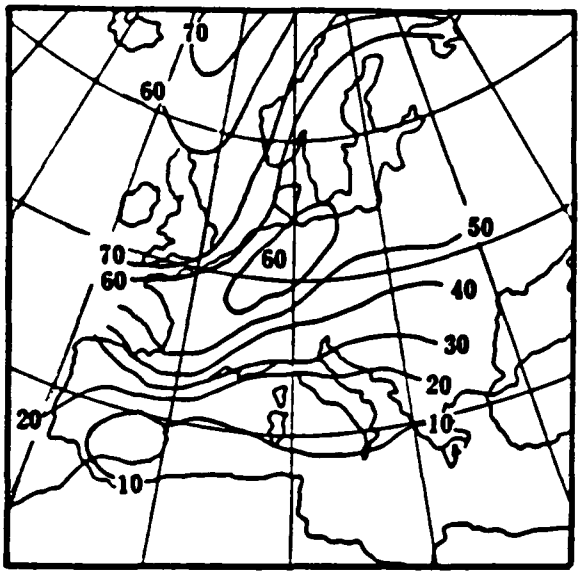
Tables 8 and 9 exhibit the occurrence of a cloud ceiling (i.e., sky cover >0.6 tenths) for Fulda. Table 8 is a summary of ceiling occurrence during four seasons in the morning and afternoon hours. In the winter months, the highest occurrence of low ceiling is not at 0600 in the morning but at 0900 GMT. Therefore, the morning hour for the winter season has been changed to 0900. The table lists the presence of a ceiling by altitude, e.g., at 0900 in winter a ceiling below 3000 ft can be found in 61 percent of the time. Since the figures in Table 8 represent cumulative frequencies, they can be used to find the frequencies of a ceiling within a particular altitude interval. Thus, a ceiling between 1500 and 3000 ft at 0900 in wintertime would occur in (61.2-41.8) percent, i.e., 19.4 percent of the time.

Table 9 was taken from Kays et al., p. 38 [10]. It summarizes the occurrence of cloud ceiling at Fulda during the daytime hours during four selected months.

Table 10 was also taken from page 39 of Reference [10]. This table permits us to evaluate not only the chances of encountering a ceiling but clouds in general. The classes of clouds are in octals of sky cover. Since no adequate information for Fulda is available, the conditions at Kassel (about 80 km north of Fulda) are substituted. Although these are not the correct numbers for Fulda and may not be reliable estimates, they serve as a guide to the order of magnitude which probably would be expected at Fulda.



0-3/10



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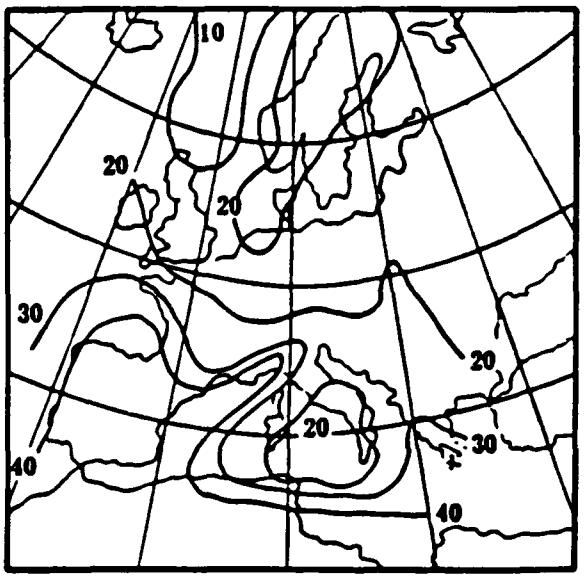
JULY



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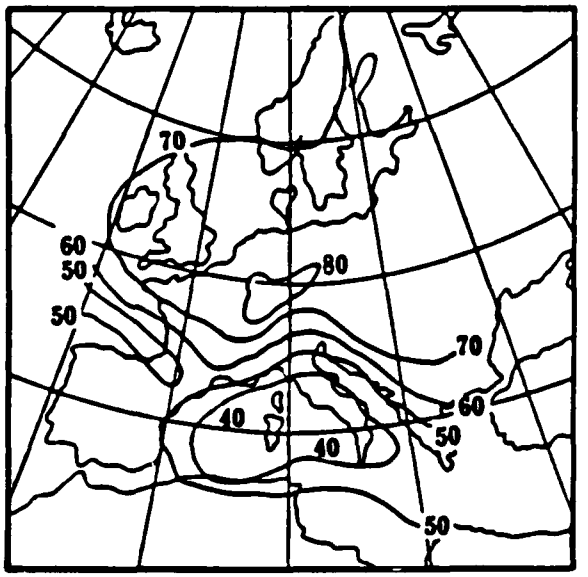

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JANUARY

Figure 2. Percent frequency contours for specified cloud cover intervals.

TABLE 8. Occurrence of Cloud Ceiling (% Frequency) Below Specified Threshold for Fulda

Season:	Hour*	Total	3	1.5	1.0	0.5	0.3	(1000 ft Unit)	obs
Winter	09	88.4	61.2	41.8	27.1	8.5	4.3%		868
	15	84.7	50.6	28.4	17.9	4.3	0.9		822
Spring	06	78.1	34.6	18.7	11.8	5.2	3.6		840
	15	82.1	28.8	8.1	3.9	0.2	0.1		873
Summer	06	74.4	23.7	16.1	11.6	7.5	4.5		840
	15	78.6	13.6	2.6	.8	.2	.0		883
Fall	06	82.5	48.9	34.2	27.6	19.9	14.5		798
	15	76.1	29.3	15.6	9.4	1.8	0.9		897

*Greenwich Time

TABLE 9. Occurrence of Cloud Ceiling (% Frequency) Below Specified Levels (Daylight Hours) for Fulda

Month	Total	10	5	3	2	1	0.5	(1000 ft Unit)
January	82.5	77.3	66.8	56.3	44.4	23.2	7.1	
April	75.2	65.4	51.3	36.6	20.4	8.0	2.4	
July	67.5	57.5	38.3	18.5	10.0	4.3	1.4	
October	72.1	63.5	52.8	40.3	31.9	19.5	13.1	

TABLE 10. Occurrence of Clouds Below Specified Level (Daylight Hours) for Kassel, Separated by Cloud Groups

	Month	Total	5	3.3	1
6-8 (ceiling)	January	82.3	64.7	58.5	5.7
	April	66.4	42.3	35.5	2.4
	July	63.9	37.9	28.4	1.7
	October	69.4	51.0	46.4	10.7
3-5 Eighth	January	7.7	11.0	7.8	0.1
	April	15.0	20.4	10.9	
	July	19.3	26.0	11.4	0.1
	October	12.5	13.8	10.0	0.2
0-2 Eighth	January	10.1	24.4	33.9	94.1
	April	18.8	37.4	53.5	97.6
	July	16.8	36.1	60.2	98.3
	October	18.2	35.2	43.7	89.0

Tables 11 and 12 contain the same information as Table 9 except that they are for the neighboring stations of Frankfurt and Hahn, respectively. This information enables the reader to judge the conditions at Fulda as listed in Table 9 and also provides some additional information to evaluate the applicability of Table 10 (from Kassel) for Fulda.

Tables 13 through 24 are sets of contingency tables for the two elements, visibility and ceiling. The first column represents classes of ceiling irrespective of cloud type. The visibility line lists the class divisions for the columns centered between them. The number of observations is designated by N at the top of each table.

The morning hours for the four seasons at Fulda, are depicted in Tables 13 through 16. Again, the hour 0900 was selected in winter because it showed a higher frequency of low ceiling and fog than the hour 0600 GMT.

The afternoon hours for the four seasons at Fulda are depicted in Tables 17 through 20. The results reflect the same tendency as the single elements of the previous sections. We have included this detailed listing so that the reader may combine fields as to his/her own uses or liking.

Tables 21 through 24 are contingency tables for Frankfurt which were added for comparision purposes but only for the fall and winter season when low ceiling and low visibility are most frequent.

TABLE 11. Occurrence of Cloud Ceiling (% Frequency) Below Specified Threshold for Frankfurt

Season:	Hour	Total	3	1.5	1.0	0.5	0.3 (1000 ft Unit)	obs
Winter	09	82.4	49.3	25.7	18.9	11.2	6.9%	2196
	15	80.6	42.0	20.0	13.6	7.3	3.9	2196
Spring	06	65.4	17.4	6.4	4.3	2.7	1.8	2205
	15	70.3	12.1	2.9	1.5	0.8	0.5	2205
Summer	06	61.2	12.4	5.6	4.3	2.9	1.7	2208
	15	69.3	6.5	1.9	1.2	0.9	0.8	2208
Fall	06	72.3	21.9	9.5	6.2	3.6	1.5	2274
	15	66.9	26.3	13.4	10.1	6.8	4.7	2274

TABLE 12. Occurrence of Cloud Ceiling (% Frequency) Below Specified Threshold for Hahn

Season:	Hour	Total	3	1.5	1.0	0.5	0.3 (1000 ft Unit)	obs
Winter	09	86.5	66.6	57.4	49.1	33.1	23.1	1565
	15	84.0	64.0	51.8	41.8	26.3	17.8	1565
Spring	06	73.6	42.3	34.2	28.4	16.7	10.8	1555
	15	80.6	32.3	14.3	9.8	4.6	2.2	1555
Summer	06	70.6	35.0	28.6	24.6	13.7	8.1	1586
	15	80.1	21.1	9.0	5.4	2.4	1.0	1586
Fall	06	77.2	53.6	45.9	39.0	27.3	20.8	1622
	15	78.1	39.8	27.2	20.0	12.4	7.8	1622

TABLE 13. Contingency Table: Visibility vs Cloud Ceiling for Fulda in the Fall (% Frequency)

Ceiling	Season Fall		Hour 06		N = 798
No Ceiling	2.3	2.3	1.0	3.4	8.6
>3000 Ft	5.8	2.0	2.1	7.0	16.7
1500-3000	0.2	1.4	1.8	5.5	5.8
1000-1500	0.0	1.4	0.8	2.9	1.6
500-1000	0.2	1.9	1.1	3.8	0.6
300-500	3.6	1.1	0.6	0.0	0.0
<300	14.2	0.2	0.1	0.0	0.0
Visibility	1	3	5	10 km	

TABLE 14. Contingency Table: Visibility vs Cloud Ceiling for Fulda in the Winter (% Frequency)

Ceiling	Season Winter		Hour 09		N = 868
No Ceiling	.8	2.5	1.5	2.5	4.3
>3000 Ft	.9	4.5	2.5	5.6	13.6
1500-3000	.1	2.6	2.8	5.5	8.3
1000-1500	.2	4.3	2.2	5.0	3.1
500-1000	1.6	8.9	2.8	4.3	1.0
300-500	2.3	1.5	0.5	0.0	0.0
<300	3.9	0.4	0.0	0.0	0.0
Visibility	1	3	5	10 km	

TABLE 15. Contingency Table: Visibility vs Cloud Ceiling for Fulda in the Spring (% Frequency)

Ceiling	Season Spring		Hour 06		N = 840
No Ceiling	1.2	3.3	2.0	4.2	11.2
>3000 Ft	3.2	3.1	2.6	10.2	24.3
1500-3000	0.1	1.4	1.4	5.2	7.7
1000-1500	0.1	1.4	1.2	2.1	2.0
500-1000	0.2	3.1	1.2	1.6	0.5
300-500	0.5	1.0	0.1	0.1	0.0
<300	3.5	0.1	0.0	0.0	0.0
Visibility	1	3	5	10 km	

TABLE 16. Contingency Table: Visibility vs Cloud Ceiling for Fulda in the Summer (% Frequency)

Ceiling	Season Summer		Hour 06 GMT		N = 840
No Ceiling	0.8	3.9	1.6	5.4	13.9
>3000 Ft	0.3	4.8	4.2	11.7	25.8
1500-3000	0.1	0.8	0.4	2.5	3.8
1000-1500	0.0	0.7	0.4	1.1	2.4
500-1000	0.4	1.6	0.5	0.8	0.8
300-500	2.0	0.6	0.0	0.4	0.0
<300	4.5	0.0	0.0	0.0	0.0
Visibility	1	3	5	10 km	

TABLE 17. Contingency Table: Visibility vs Cloud Ceiling for Fulda in the Fall (% Frequency)

Ceiling	Season Fall		Hour 15 GMT		N = 897
No Ceiling	0.0	0.6	1.0	4.1	17.4
>3000 Ft	0.0	0.8	1.3	7.0	38.5
1500-3000	0.0	1.0	0.9	3.6	8.2
1000-1500	0.0	1.0	1.1	2.3	1.8
500-1000	0.6	1.8	1.2	3.2	0.8
300-500	0.5	0.1	0.3	0.0	0.0
<300	0.9	0.0	0.0	0.0	0.0
Visibility	1	3	5	10 km	

TABLE 18. Contingency Table: Visibility vs Cloud Ceiling for Fulda in the Winter (% Frequency)

Ceiling	Season Winter		Hour 15 GMT		N = 822
No Ceiling	0.0	2.4	2.0	3.8	7.2
>3000 Ft	0.4	3.5	3.2	7.5	19.5
1500-3000	0.2	1.8	2.0	7.4	10.8
1000-1500	0.0	2.3	2.1	3.8	2.3
500-1000	0.7	5.1	1.5	4.7	1.6
300-500	1.6	1.1	0.4	0.2	0.1
<300	0.9	0.0	0.0	0.0	0.0
Visibility	1	3	5	10 km	

TABLE 19. Contingency Table: Visibility vs Cloud Ceiling for Fulda in the Spring (% Frequency)

Ceiling	Season Spring		Hour 15 GMT		N = 873
No Ceiling	0.0	0.0	0.3	2.2	15.4
>3000 Ft	0.0	0.3	0.2	5.3	47.5
1500-3000	0.1	0.3	1.3	3.9	15.0
1000-1500	0.0	0.1	0.5	2.2	1.5
500-1000	0.0	0.9	0.8	1.4	0.6
300-500	0.0	0.1	0.0	0.0	0.0
<300	0.1	0.0	0.0	0.0	0.0
Visibility	1	3	5	10 km	

TABLE 20. Contingency Table: Visibility vs Cloud Ceiling for Fulda in the Summer (% Frequency)

Ceiling	Season Summer		Hour 15 GMT		N = 883
No Ceiling	0.0	0.0	0.0	0.3	21.1
>3000 Ft	0.0	0.0	0.2	3.7	61.0
1500-3000	0.0	0.0	0.1	1.7	9.2
1000-1500	0.0	0.0	0.2	0.7	0.9
500-1000	0.0	0.0	0.0	0.2	0.3
300-500	0.0	0.1	0.0	0.1	0.0
<300	0.0	0.0	0.0	0.0	0.0
Visibility	1	3	5	10 km	

TABLE 21. Contingency Table: Visibility vs Cloud Ceiling for Frankfurt in the Fall (% Frequency)

Ceiling	Season Fall		Hour 06 GMT		N = 2274
No Ceiling	2.9	8.2	3.5	6.8	7.6
>3000 Ft	1.3	7.6	4.3	9.5	14.2
1500-3000	0.1	2.3	1.4	4.0	6.5
1000-1500	0.0	1.2	0.4	1.0	1.0
500-1000	0.2	1.5	0.8	1.1	0.2
300-500	0.5	1.8	0.3	0.0	0.1
<300	8.0	1.5	0.0	0.2	0.1
Visibility	1	3	5	10 km	

TABLE 22. Contingency Table: Visibility vs Cloud Ceiling for Frankfurt in the Winter (% Frequency)

Ceiling	Season Winter		Hour 09 GMT		N = 2196
No Ceiling	0.7	5.1	2.2	4.1	5.6
>3000 Ft	0.5	8.0	3.7	7.7	13.2
1500-3000	0.4	5.4	3.1	5.5	9.2
1000-1500	0.4	2.9	0.9	1.8	1.2
500-1000	0.7	4.6	0.7	1.1	0.5
300-500	1.2	2.6	0.4	0.1	0.0
<300	5.2	0.6	0.0	0.0	0.1
Visibility	1	3	5	10 km	

TABLE 23. Contingency Table: Visibility vs Cloud Ceiling for Frankfurt in the Fall (% Frequency)

Ceiling	Season Fall		Hour 15 GMT		N = 2274
No Ceiling	0.0	0.9	1.0	4.0	21.7
>3000 Ft	0.1	3.1	2.1	8.8	36.4
1500-3000	0.1	1.5	1.2	3.8	5.8
1000-1500	0.1	0.9	0.4	1.3	0.6
500-1000	0.2	1.6	0.3	0.4	0.1
300-500	0.4	1.5	0.2	0.1	0.0
<300	1.1	0.1	0.1	0.0	0.2
Visibility	1	3	5	10 km	

TABLE 24. Contingency Table: Visibility vs Cloud Ceiling for Frankfurt in the Winter (% Frequency)

Ceiling	Season Winter		Hour 15 GMT		N = 2196
No Ceiling	0.3	0.5	1.4	5.0	10.5
>3000 Ft	0.5	4.7	3.0	8.5	21.8
1500-3000	0.3	4.1	2.4	4.9	10.4
1000-1500	0.0	2.6	0.9	1.7	1.2
500-1000	0.9	3.8	0.6	0.9	0.1
300-500	1.4	2.0	0.1	0.0	0.0
<300	3.0	0.5	0.0	0.0	0.4
Visibility	1	3	5	10 km	

C. Adverse Weather

Tables 25 through 35 give climatological information about "adverse weather" which is specified in all tables except Tables 30, 34, and 35 as ceiling and fog. In these tables ceiling was chosen for two altitude levels, under 3000, and 4500 ft. In addition, ceiling was limited to sky cover $\geq$7.5 tenths instead of the customary $\geq$6 tenths of sky cover. This reduces the occurrence of adverse weather by approximately 7-10 percent.

Table 25 exhibits the climatological chances for adverse weather at three stations for the four seasons, and four different groups of adverse weather. It is obvious that the frequency of occurrence of adverse weather at more than one station simultaneously is lower. We learn from Table 26 that the chances of adverse weather occurring at six stations (see Fig. 1) are below 10 percent in every season except winter.

Table 27 shows the diurnal variation of adverse weather as previously defined for the four seasons and two stations. Estimates on the chances of encountering adverse weather during the night at Fulda were prepared, based on multiple regression techniques, by utilizing surrounding stations. It must be repeated that these estimates are not averages over six stations but calculated estimates.

Table 28, Parts A, B, and C provide information about the duration of adverse weather. Only selected thresholds of the cumulative distribution are included here. The data for Frankfurt and Hahn are climatic values from the period 1966-1976. The estimates for Fulda have been obtained by utilizing a modified exponential distribution (see Essenwanger [11]) and the adverse weather probabilities given in Table 25.

Table 29 adds more information to the duration of adverse weather. Instead of cumulative thresholds of probability, here the cumulative probabilities for certain classes of hours were used. We were only able to provide these tables for Frankfurt and Hahn because the exponential model which was taken to derive the estimates of Table 28 was not suitable to calculate the five extremes.

Table 30 is based on a different definition of adverse weather by defining adverse weather conditions when the visibility drops below 5 km. This table is included for information purposes even though the climatic information is for Kassel. The column under B lists the percentage of time the adverse weather condition occurred in the given month.

TABLE 25. Single Station Probabilities of Adverse Weather (Seasonal Summary)

Season	≤4500 ft						≤3000 ft					
	Ceiling ≥0.6			Ceiling ≥0.75			Ceiling ≥0.6			Ceiling ≥0.75		
	Fu	Ha	Fr	Fu	Ha	Fr	Fu	Ha	Fr	Fu	Ha	Fr
Sp	41%	47	35%	32%	39	26%	32%	39	22%	25%	33	16%
Su	31	33	22	22	24	13	24	26	14	17	20	8
Fa	43	51	40	36	45	35	36	46	31	31	40	26
Wi	64	79	61	59	74	56	57	75	51	51	70	47
Year	45	52	39	37	45	32	37	47	29	31	41	24

Fu = Fulda, Ha = Hahn, Fr = Frankfurt

Table 26. Four to Six Station Probabilities of Adverse Weather (Season and Annual Summary)

Season	4 Stations				5 Stations				6 Stations			
	≤4500 ft		≤3000 ft		≤4500 ft		≤3000 ft		≤4500 ft		≤3000 ft	
	≥0.6	≥0.75	≥0.6	≥0.75	≥0.6	≥0.75	≥0.6	≥0.75	≥0.6	≥0.75	≥0.6	≥0.75
Spring	32%	23	19	14%	20%	12	10	7%	8%	4	3	2%
Summer	16	9	10	6	8	4	4	3	3	1.5	1.5	1
Fall	32	25	22	18	18	14	13	10	8	6	5	4
Winter	58	51	47	43	37	32	32	27	22	18	16	13
Year	34	27	25	20	21	16	15	12	10	7	6	5

TABLE 27. Diurnal Variation of Adverse Weather for Fulda and Frankfurt*

Season	Hour	Ceiling <3000 ft, Vis <1 km				Ceiling <4500 ft, Vis <1 km			
		>0.6		>0.75		>0.6		>0.75	
		Fu	Fr	Fu	Fr	Fu	Fr	Fu	Fr
Spring	00	36%	12	33	11	43	23	39	21%
	03	38	17	34	16	45	26	49	25
	06	38	19	23	18	47	29	27	27
	09	35	21	17	18	44	30	21	26
	12	30	18	15	15	45	30	18	26
	15	26	12	11	12	41	22	13	21
	18	18	10	16	9	28	20	23	18
	21	(20)	11	(17)	10	(30)	20	(26)	17
Summer	00	35%	6	32	5	42	11	39	10%
	03	36	10	32	8	44	15	39	13
	06	29	11	18	9	37	15	21	13
	09	25	15	10	12	32	20	12	18
	12	23	10	9	9	40	19	12	14
	15	14	5	6	5	27	12	9	11
	18	10	4	7	4	17	10	12	10
	21	(13)	6	(9)	5	(17)	12	(12)	10
Fall	00	57%	25	56	23	64	34	63	32%
	03	57	32	56	31	64	41	62	39
	06	56	37	34	35	67	45	37	48
	09	46	35	24	33	56	45	28	43
	12	35	31	14	27	49	40	17	37
	15	27	22	12	20	42	31	16	29
	18	27	20	21	18	34	31	26	28
	21	(33)	20	(28)	19	(40)	30	(39)	28
Winter	00	60%	41	56	39	66	53	62	50%
	03	60	44	57	41	65	56	62	53
	06	59	49	34	46	69	61	36	58
	09	60	45	33	43	68	57	35	55
	12	55	45	27	43	65	56	30	54
	15	52	43	23	41	62	54	27	52
	18	60	39	58	37	68	53	64	50
	21	(58)	40	(55)	38	(66)	53	(63)	51

*Unit: Percentage occurrence of adverse weather, Fulda 1968-76, Frankfurt 1966-77.

TABLE 28. Duration of Adverse Weather (Selected Thresholds) in Hours

A. Frankfurt

%	[a] h ≤4500, Ceiling ≥0.6				[b] h ≤4500, Ceiling ≥0.75				[c] h ≤3000, Ceiling ≥0.6				[d] h ≤3000, Ceiling ≥0.75			
	Sp	Su	Fa	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa	Wi
50	6.3	4.1	7.2	10.0	4.8	4.0	5.8	9.0	4.2	4.0	5.7	7.7	4.2	4.3	4.9	7.3
90	20.6	14.2	25.0	48.0	16.0	13.2	21.0	39	16.5	12.4	16.5	34	16.5	13.0	19.5	31
95	28.5	17.7	44.5	64.0	24.7	16.5	40.5	58	22.5	16.0	39.0	54	22.5	19.5	42	49.5
99	72.0	34.5	108	100	72	34.5	108	87	45	27	99	96	39	30	108	87
Max	111	39	246	117	108	37	243	117	61	34	246	117	50	31	243	117
N	229	222	223	207	200	139	193	220	195	154	196	208	140	83	163	205
N_s	76	74	74	69	67	36	64	73	65	51	65	69	47	28	54	68

B. Hahn

%																
50	9.0	6.5	8.7	18.0	7.5	5.4	7.2	12.5	7.7	6.7	8.3	14.9	6.4	5.0	6.7	11.8
90	30.0	20.6	42.9	78.0	25.5	16.5	31.5	62.0	24.0	18.7	35.0	72	22.5	16.0	29.0	52
95	42.0	34.5	64	120.0	33	24.5	46.5	80	36.5	32.0	52	120	28.0	25.5	39	75
99	93	70	135	160	73.5	49.5	102	138	93	65	102	135	63	57	102	114
Max	144	75	219	174	117	75	219	156	144	75	219	174	117	75	219	132
N	219	209	197	159	217	183	220	195	208	175	202	174	209	158	217	214
N_s	73	66	66	53	72	61	73	65	69	58	67	58	70	53	72	71

N_s = per season

C. Fulda (Estimates)

50	7	5	8	12	6	4	6	10	6	5	7	8	6	5	6	8
90	25	17	32	63	20	15	25	50	20	15	25	40	20	16	26	38
95	35	25	50	90	30	19	43	70	30	24	45	70	30	25	47	68
99	82	50	120	130	70	40	105	110	60	45	100	110	50	48	102	95

TABLE 29. Duration of Adverse Weather (Single Stations)

Hours	Spring								Summer							
	a		b		c		d		a		b		c		d	
	Fr	Ha	Fr	Ha	Fr	Ha	Fr	Ha	Fr	Ha	Fr	Ha	Fr	Ha	Fr	Ha
	%	%							%	%						
>0 to <6	40.2	26.0	48.0	29.0	56.4	25.5	56.4	33.5	54.5	36.8	61.2	43.2	59.7	34.3	53.0	46.2
>9 to <15	81.7	64.4	87.5	74.2	88.3	70.7	88.6	78.6	88.8	78.0	90.7	84.2	92.8	78.8	92.2	86.1
>21 to <27	94.0	86.8	96.5	89.8	96.0	91.5	96.4	93.3	98.0	91.4	98.0	95.7	98.6	92.5	98.6	95.0
>45 to <51	98.7	97.0	98.7	97.7	99.5	97.1	100.0	98.6	100.0	97.5	100.0	98.9	100.0	97.7	100.0	98.7
>69 to <75	99.1	98.5	99.1	99.1	100.0	98.6		99.0				99.5		99.4		99.4
5 Extremes	(Hours converted to days)								(Hours converted to days)							
1st	4.6	6.0	4.5	4.9	2.5	6.0	2.0	4.9	1.6	3.1	1.5	3.1	1.4	3.1	1.2	3.1
2nd	4.5	4.6	3.4	4.5	2.0	4.1	1.6	4.1	1.5	2.9	1.5	2.4	1.1	2.8	1.0	2.4
3rd	2.1	3.9	2.1	2.6	1.8	3.9	1.6	2.6	1.2	2.8	1.1	1.9	1.0	2.4	0.9	1.9
4th	2.0	2.6	1.6	2.2	1.6	2.3	1.5	2.0	1.2	2.5	1.0	1.8	1.0	2.1	0.9	1.6
5th	1.8	2.4	1.4	2.1	1.6	2.2	1.4	1.9	1.0	2.1	0.9	1.5	0.9	1.8	0.8	1.5
N	229	219	200	217	195	208	140	219	222	209	139	183	154	175	83	158

Hours	Fall								Winter							
>0 to <6	37.7	26.9	38.3	30.0	40.8	30.2	42.9	34.6	25.1	18.9	29.2	25.1	35.6	20.1	34.1	26.2
>9 to <15	78.6	66.0	79.2	72.7	82.1	69.3	82.8	76.1	58.9	44.6	64.8	53.2	67.4	47.1	68.2	54.2
>21 to <27	90.7	80.8	90.7	86.8	93.3	85.2	92.0	89.0	76.2	61.5	78.2	69.2	82.8	68.2	82.8	74.8
>45 to <51	96.0	91.8	96.1	95.8	96.3	94.0	95.6	96.3	89.9	81.6	92.6	86.2	94.0	84.2	95.1	89.5
>69 to <75	97.3	97.0	98.0	97.7	97.4	97.5	97.5	97.7	96.6	88.6	97.2	92.8	97.6	90.3	98.0	94.5
5 Extremes	(Hours converted to days)								(Hours converted to days)							
1st	10.2	9.1	10.1	9.1	10.2	9.1	10.1	9.1	4.9	7.3	4.9	6.5	4.9	7.3	4.9	5.5
2nd	7.3	7.5	5.9	7.0	4.5	7.5	4.5	7.0	4.8	6.5	4.0	6.0	4.6	6.2	4.0	5.0
3rd	4.5	5.6	4.5	4.3	4.1	4.3	4.1	4.2	3.6	6.4	3.6	5.9	4.0	5.6	3.6	4.8
4th	4.0	4.3	3.1	4.0	3.6	3.9	3.1	3.8	3.4	5.9	3.4	5.8	3.6	5.3	3.4	4.5
5th	3.6	4.0	2.5	3.8	3.4	3.8	2.4	3.6	3.4	5.8	3.4	5.5	3.4	5.0	3.0	4.2
N	223	197	193	220	196	202	163	217	207	159	216	195	208	174	205	214

TABLE 30. Percent of Time That Cloud Ceilings Below 900 M (3000 ft) and/or Visibility Below 5 km Persisted for Specified Number of Hours After The Beginning at Kassel

Month	B*	Hours												
		3	6	9	12	15	18	21	24	30	36	42	48	60
January	63.3	83	73	65	58	51	46	41	38	32	28	23	19	14
April	25.9	62	42	29	20	14	10	8	6	4	2	1	1	0
July	16.7	54	32	17	8	4	1	--	--	--	--	--	--	--
October	48.9	77	63	52	40	31	25	20	18	14	10	7	6	4

*B = Percentage of time adverse weather condition occurred during month.

The top part of Table 31 depicts the average percentages of adverse weather for six stations (see Fig. 1) in the Fulda neighborhood and the bottom part lists the chances of having adverse weather, simultaneously, at all four to six stations.

Table 32 shows the seasonal breakdown of the data presented in Table 31. Some readers may be surprised that fall appears as the season with a longer duration of adverse weather than any other season if four stations are considered. For five stations fall and winter are about equal, but for six stations winter is the worst season.

Table 33 provides a diurnal breakdown of the data in Table 31. For most of the data the morning hours have the highest climatic probability of adverse weather.

Finally, Tables 34 and 35 deal with the spatial distribution of adverse weather (see Essenwanger and Levitt [12]). Only the fall and winter seasons are included here. Adverse weather is defined for various categories but again is different from the previous definition used in Tables 25 and 26. Tables 34 and 35 reflect the variation from the best to the worst combination, e.g. at 0100 hours, ceiling <500 ft and/or visibility under 2 miles, the adverse weather probability ranges from 9.3 percent to 26.3 percent for the station with the least to the station with the highest occurrence during the fall. Data provided in these tables are based on the four stations Frankfurt, Heidelberg, Saarbrucken, and Hahn.

Total monthly precipitation for Fulda is not given in the RUSSWO [13] because of gaps in observations on weekends and holidays. Considerable evaporation can occur during these gaps, and it is uncertain when measured precipitation actually fell.

Monthly and annual means of precipitation for five stations in the general vicinity of Fulda are included in tables published by the Meteorological Office of Great Britain [14], and in this report as Part A of Table 36. Four of the five stations have annual mean precipitation in the range 23-27 inches. Brocken has an annual mean precipitation of 65 inches. This is probably the result of an orographic effect because Brocken is at an elevation of 1150 m. The other four stations are at elevations less than half as high. Fulda is at an elevation of 305 m.

The amount of precipitation has a seasonal variation. At the four lower stations, the amount of precipitation in summer is one and one-half to two times as large as the amount of precipitation in winter. The ratio of summer to winter precipitation at Fulda is 1.5 on Kassner's [15] detailed map of this ratio in Germany. Ratios in the immediate vicinity of Fulda are near this value. Ratios are significantly higher a few tens of kilometers to the northeast of Fulda, and they are much lower about the same distance to the northwest to Fulda.

The areal mean rainfall for the entire Federal Republic of Germany is nonzero on 90 percent of the days in July and August and exceeds 1.0 mm on 60 percent of the days in these two months [16]. On 5 percent of the days in July and August, the areal mean rainfall for the Federal Republic of Germany exceeds 10 mm.

TABLE 31. Four to Six Station Probabilities of Adverse Weather
(Season and Annual Summary)

Season	4 Stations				5 Stations				6 Stations			
	≤4500 ft		≤3000 ft		≤4500 ft		≤3000 ft		≤4500 ft		≤3000 ft	
	≥0.6	≥0.75	≥0.6	≥0.75	≥0.6	≥0.75	≥0.6	≥0.75	≥0.6	≥0.75	≥0.6	≥0.75
Spring	32%	23	19	14%	20%	12	10	7%	8%	4	3	2%
Summer	16	9	10	6	8	4	4	3	3	1.5	1.5	1
Fall	32	25	22	18	18	14	13	10	8	6	5	4
Winter	58	51	47	43	37	32	32	27	22	18	16	13
Year	34	27	25	20	21	16	15	12	10	7	6	5

Hours of Simultaneous Adverse Weather at Four to Six Stations

Percent												
50	7.9	6.9	6.4	6.3	6.0	5.6	6.0	6.0	5.0	4.9	5.1	5.0
90	24.5	22.0	19.5	18.0	15.2	14.0	14.2	14.0	12.0	12.0	12.0	12.0
95	42.5	39.0	33.0	30.0	33.0	30.0	18.0	16.0	15.0	14.0	14.0	14.0
99	75	69	69	66	69	66	66	66	36	24	24	18
Max	228	225	228	225	108	108	81	81	54	40	33	24
N	707	583	573	466	610	462	414	324	332	225	199	152

TABLE 32. Seasonal Breakdown of the Duration of Simultaneous Adverse Weather at Four to Six Stations

A. Four Stations

%	Condition a h ≤4500, Ceiling ≥0.6				Condition b h ≤4500, Ceiling ≥0.75				Condition c h ≤3000, Ceiling ≥0.6				Condition d h ≤3000, Ceiling ≥0.75			
	Sp	Su	Fa	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa	Wi
50	7	6	7	12	6	5	6	11	5	5	5	8	5	5	4	7
90	27	18	24	49	26	16	22	40	22	15	23	40	21	14	22	36
95	42	24	40	66	42	21	34	57	36	18	33	54	33	18	32	51
99	72	38	120	90	69	34	102	78	57	34	105	78	45	33	100	72
Max	111	42	228	135	108	36	225	96	63	42	228	132	48	36	225	78
N	175	143	190	187	134	78	166	196	143	101	146	183	103	57	121	180
N_s	58	46	63	62	45	26	55	65	48	34	49	61	34	19	40	60

B. Five Stations

50	6	5	5	8	5	4	5	7	4	5	4	7	4	4	4	6
90	18	15	16	34	16	13	15	25	16	12	16	27	15	11	16	24
95	24	17	27	50	21	16	25	44	22	14	28	42	19	14	27	40
99	59	19	60	81	52	30	55	75	36	18	50	68	30	16	50	66
Max	63	21	108	108	57	33	108	84	42	21	69	81	33	18	69	81
N	160	100	144	201	111	52	116	183	90	55	95	173	63	32	74	154
N_s	53	33	48	67	37	17	29	61	30	18	32	58	21	11	25	51

C. Six Stations

50	4	4	4	7	4	4	4	7	4	3	4	7	4	3	4	6
90	10	8	10	13	10	5	10	13	9	5	10	14	9	5	9	13
95	12	9	12	22	12	6	12	18	10	6	12	18	11	6	11	15
99	22	12	14	50	14	7	14	26	13	7	13	28	13	6	13	19
Max	24	15	15	54	15	9	15	40	15	9	15	33	15	9	15	24
N	95	44	75	118	51	19	49	106	42	20	42	95	24	9	35	84
N_s	32	15	25	29	17	6	16	35	14	7	14	32	8	3	12	28

N_s = per season

TABLE 33. Four to Six Station Probability of Adverse Weather (3-Hourly Intervals)

Season		4 Stations				5 Stations				6 Stations			
	Hour	A	B	C	D	A	B	C	D	A	B	C	D
Spring													
	00	(24)	(20)	(14)	(11)	(9)	(8)	(4)	(3)	(3)	(3)	(1)	(1)
	03	(30)	(27)	(18)	(17)	(14)	(11)	(7)	(5)	(5)	(4)	(2)	(2)
	06	38.4	29.7	27.2	20.3	26.8	20.3	17.8	14.5	12.0	6.5	5.8	3.3
	09	42.4	28.3	30.8	20.3	31.2	18.5	17.8	11.6	13.8	5.8	6.9	4.3
	12	46.7	26.1	27.5	15.6	33.3	14.1	15.9	8.7	15.2	6.9	5.4	3.6
	15	35.5	20.7	17.8	12.0	22.5	11.6	11.6	6.9	8.7	5.1	2.9	2.5
	18	20.3	16.7	10.1	8.3	11.6	6.5	4.3	1.4	3.6	1.8	0.7	0.0
	21	(20)	(15)	(9)	(8)	(9)	(4)	(4)	(2)	(3)	(1)	(1)	(1)
Summer													
	00	(7)	(6)	(6)	(5)	(2)	(2)	(1)	(1)	(1)	(1)	(1)	(1)
	03	(11)	(9)	(9)	(8)	(4)	(3)	(3)	(3)	(1)	(1)	(1)	(1)
	06	19.9	14.1	14.5	10.1	12.3	6.9	6.9	4.7	4.0	1.1	1.8	0.4
	09	30.8	14.9	20.7	10.5	17.4	8.0	9.8	6.2	7.2	1.8	4.0	1.4
	12	27.2	11.6	14.1	6.2	15.9	5.4	5.1	2.5	5.4	2.2	1.1	0.7
	15	18.1	6.9	6.9	4.0	8.7	4.3	4.0	1.8	4.3	2.5	1.8	1.1
	18	8.0	5.1	3.3	1.8	3.6	1.8	1.1	0.4	1.1	0.0	0.0	0.0
	21	(6)	(4)	(4)	(2)	(2)	(2)	(1)	(1)	(1)	(1)	(1)	0
Fall													
	00	(24)	(20)	(16)	(15)	(11)	(11)	(10)	(9)	(4)	(3)	(3)	(3)
	03	(33)	(27)	(28)	(18)	(16)	(15)	(14)	(12)	(7)	(5)	(5)	(4)
	06	39.9	32.6	30.4	26.0	25.6	22.7	18.3	16.5	11.7	8.4	7.7	6.6
	09	47.3	37.0	36.6	28.2	31.5	22.0	20.9	16.1	15.0	11.0	10.3	7.7
	12	39.6	27.5	27.5	19.8	25.3	16.5	18.7	11.4	13.6	8.1	8.8	5.5
	15	30.4	22.0	19.8	13.6	20.1	14.3	11.7	8.4	8.8	5.1	4.4	3.3
	18	19.8	15.8	12.8	10.6	7.7	5.5	4.0	3.7	(3)	(3)	(2)	(2)
	21	(18)	(15)	(11)	(10)	(5)	(4)	(3)	(3)	(2)	(2)	(1)	(1)
Winter													
	00	(52)	(47)	(42)	(37)	(30)	(27)	(22)	(18)	(17)	(15)	(11)	(10)
	03	(59)	(54)	(45)	(42)	(33)	(30)	(30)	(27)	(22)	(19)	(16)	(15)
	06	66.4	60.5	50.9	48.0	36.5	32.8	47.6	41.7	27.7	23.6	21.4	17.7
	09	67.2	57.2	54.2	46.1	20.6	40.6	40.6	32.1	29.9	21.8	21.0	15.9
	12	64.9	55.0	52.4	44.3	48.7	39.5	40.6	33.6	27.3	20.3	21.8	17.0
	15	60.1	49.8	51.3	60.1	43.5	32.8	34.7	26.2	22.1	16.2	14.4	12.2
	18	51.3	43.9	40.2	33.2	31.4	25.1	18.8	15.9	(15)	(13)	(10)	(9)
	21	(46)	(41)	(40)	(34)	(26)	(25)	(20)	(18)	(14)	(12)	(10)	(9)

TABLE 34. Range of Adverse Weather Probability in the Fall (Single Station Through Four Station)*

HR	1-STA	2-STA	3-STA	4-STA	1-STA	2-STA	3-STA	4-STA
	C<500 ft and/or V<2 mi				C<800 ft and/or V<3 mi			
1	9.3% 26.3	5.4% 14.9	3.9% 6.4	3.4%	16.7% 34.6	10.8% 21.4	7.7% 11.3	7.0%
4	12.2 34.1	7.8 19.3	5.8 8.1	5.1	20.4 44.0	14.3 29.2	10.8 14.5	9.7
7	20.6 38.5	12.0 23.9	8.5 12.0	7.5	31.0 54.2	20.0 35.3	15.5 20.8	14.5
10	18.6 32.3	10.0 18.5	6.2 8.8	5.1	30.3 48.7	19.2 30.9	13.5 17.5	12.1
13	11.7 17.2	4.4 8.9	2.5 3.6	2.1	20.3 25.3	8.9 14.4	6.4 7.6	5.2
16	9.5 14.7	3.2 6.7	2.1 3.1	1.7	16.4 21.5	7.6 11.4	5.3 6.5	4.3
19	8.2 17.0	3.5 8.6	2.3 3.4	1.8	15.5 24.5	9.2 13.9	6.3 7.6	5.2
22	8.8 19.6	4.6 10.3	3.1 4.6	2.5	15.0 27.0	9.0 15.6	5.9 8.1	5.5
	C<2000 ft and/or V<4 mi				C<8000 ft and/or V<5 mi			
1	24.5% 52.1	18.6% 36.6	14.5% 21.5	13.7%	57.4% 73.3	47.8% 57.4	41.7% 47.0	38.5%
4	28.2 60.7	21.4 42.9	17.1 27.7	15.8	63.0 79.6	54.2 65.2	47.6 54.2	44.1
7	42.0 72.0	30.8 51.6	25.7 36.8	24.5	74.0 86.2	62.4 74.6	56.6 61.0	54.1
10	42.8 69.8	30.2 49.3	24.3 32.4	23.2	69.9 83.1	56.8 71.2	51.0 58.7	49.3
13	32.0 50.9	19.9 33.5	14.3 18.7	12.9	61.7 69.2	47.1 54.1	40.1 44.6	36.7

*See footnote at end of table.

TABLE 34. Range of Adverse Weather Probability in the Fall (Single Station Through Four Station) - Continued

HR	1-STA	2-STA	3-STA	4-STA	1-STA	2-STA	3-STA	4-STA
	C<2000 ft and/or V<4 mi				C<8000 ft and/or V<5 mi			
16	25.3 37.6	16.3 24.7	11.7 14.1	10.3	52.2 59.2	39.2 45.8	33.2 36.9	29.6
19	22.8 38.4	17.4 25.8	13.3 16.3	11.5	54.5 62.8	42.1 48.6	35.4 39.7	32.4
22	23.3 42.2	17.5 27.5	13.7 17.0	12.8	55.3 67.9	43.3 50.6	36.9 41.5	33.9

*Data from Sep-Oct-Nov (Local Standard Time) 1967-1976.

TABLE 35. Range of Adverse Weather Probability in the Winter (Single Station Through Four Station)*

HR	1-STA	2-STA	3-STA	4-STA	1-STA	2-STA	3-STA	4-STA
	C<500 ft and/or V<2 mi				C<800 ft and/or V<3 mi			
1	14.2% 42.0	7.3% 23.7	5.2% 7.8	4.2%	25.1% 53.4	14.7% 37.1	11.4% 15.9	10.1%
4	15.2 44.0	7.3 27.2	5.0 10.0	4.1	24.9 56.3	14.7 40.1	11.6 18.9	10.0
7	16.7 46.3	8.7 26.9	6.3 11.1	5.1	26.6 58.3	17.4 41.8	14.3 21.4	12.6
10	24.0 48.2	13.9 29.2	9.3 14.3	7.9	37.8 59.6	28.3 45.1	23.1 28.0	20.0
13	19.9 40.9	10.3 21.6	6.7 9.3	5.0	31.9 49.9	19.8 34.7	14.8 19.6	12.9
16	17.0 36.7	8.7 17.2	5.9 8.3	5.0	28.2 46.1	18.1 29.9	13.3 16.8	11.3

*See footnote at end of table.

TABLE 35. Range of Adverse Weather Probability in the Winter (Single Station Through Four Station) - Continued

HR	1-STA	2-STA	3-STA	4-STA	1-STA	2-STA	3-STA	4-STA
	C<500 ft and/or V<2 mi				C<800 ft and/or V<3 mi			
19	14.6 36.9	7.1 18.6	4.8 6.0	3.4	24.8 48.0	14.6 31.3	10.8 14.2	8.9
22	14.4 36.8	6.1 22.1	4.2 7.1	3.6	24.6 50.0	13.7 32.7	10.3 14.4	8.6
	C<2000 ft and/or V<4 mi				C<8000 ft and/or V<5 mi			
1	39.8% 70.0	30.0% 59.2	26.9% 38.0	25.7%	72.6% 84.4	63.6% 74.8	58.6% 65.0	55.7%
4	41.2 73.1	31.8 61.8	28.9 39.9	27.7	75.6 87.1	66.6 78.6	62.4 68.4	59.8
7	43.4 75.7	33.9 63.3	30.8 43.6	29.3	78.9 87.2	70.6 78.8	65.9 70.8	62.8
10	52.0 77.7	43.4 63.3	37.6 48.1	35.8	82.1 89.9	72.9 78.8	67.1 72.0	65.2
13	48.3 73.1	37.6 59.0	31.7 40.9	29.3	78.4 86.8	68.4 75.3	62.2 66.2	59.3
16	41.9 65.2	32.0 51.7	26.3 34.3	23.7	74.9 78.9	64.1 68.4	57.6 60.0	53.0
19	39.6 65.4	30.6 53.0	26.4 35.4	25.0	73.2 82.3	63.9 71.9	58.3 63.9	55.7
22	38.4 67.3	29.3 54.9	25.4 36.4	24.4	72.3 83.0	62.6 73.3	57.2 64.8	54.7

*Data from Dec-Jan-Feb (Local Standard Time) 1967-1976.

The probability that precipitation will fall sometime during a given day at any one site in the Fulda area is significant. Reich's [17] study shows that more than half of the days of the year have at least 0.1 mm of precipitation in the extreme southwest of the German Democratic Republic near Fulda. The statistics published by the Meteorological Office of Great Britain [14] use the higher threshold of 1.0 mm. Part B of Table 36 contains monthly and annual average number of days with at least 1.0 mm of precipitation at five stations in the vicinity of Fulda. At four of these stations, approximately one-third of the days have precipitation amounts at least as large as 1.0 mm. Approximately half of the days have 1.0 mm or more of precipitation at the high mountain station of Brocken.

The number of days with precipitation does not vary a lot from month to month. There is a tendency for July, August, and December to have one or two more days with precipitation than most of the other months. The seasonal distribution is different at Brocken where January has the largest number of days with precipitation at least 1.0 mm. February has a lower than average number of days with at least 1.0 mm of precipitation at all five stations.

Distributions of daily and monthly amounts of precipitation are positively skewed. This means that they have a long right tail. There are many days with little or no precipitation and a few days with large amounts of precipitation.

Part C of Table 36 contains the maximum amount of precipitation in 24 hours for each month for the same five stations listed in Part A of Table 36. All ratios of maximum precipitation in 24 hours to monthly mean precipitation are greater than 0.30 at these five stations. The maximum precipitation in 24 hours is greater than the monthly mean in each of the following: May and June at Frankfurt am Main, April at Hof, and September at Brocken. The elevations of these three stations are 103 m for Frankfurt, 477 m for Hof, and 1150 m for Brocken. The absolute value of maximum precipitation in 24 hours is greater at Brocken where the monthly means are higher.

Skewness of distributions of precipitation at sites near Fulda in the German Democratic Republic can be estimated from the work of Reich [17]. Daily and monthly precipitation amounts are fitted with a Weibull distribution in Reich's work. Skewness is a unique function of the shape parameter in the Weibull distribution [11, 18]. Shape parameters less than 3.6 are associated with positive skewness. Daily sums of precipitation have smaller Weibull shape parameters than monthly sums, and it follows that distributions of daily precipitation are more highly skewed than distributions of monthly precipitation. In the extreme southwestern part of the German Democratic Republic, skewness of daily sums of precipitation is near 4, and skewness of monthly sums is near 0.7 for the years 1951-1965. Reich's [19] later investigation of the distribution of the maximum daily amount of precipitation for each individual month during the years 1951-1965 also shows a skewness near 0.7 in the part of the German Democratic Republic nearest Fulda.

TABLE 36. Precipitation at Stations Near Fulda

Station	Month J	F	M	A	M	J	J	A	S	O	N	D	Year
A. Monthly and Annual (in inches)*													
Frankfurt	1.7	1.3	1.6	1.5	2.0	2.5	2.8	2.6	1.9	2.2	2.0	2.0	24.1
Kassel	1.6	1.4	1.5	1.6	1.9	2.3	3.0	2.6	1.9	1.9	1.7	1.9	23.3
Hof	2.0	1.6	1.9	2.0	2.3	2.9	3.2	3.0	2.1	1.9	1.9	2.1	26.9
Nuremberg	1.5	1.2	1.3	1.7	2.2	2.5	3.1	3.1	2.1	2.1	1.9	1.7	24.4
Brocken	5.9	6.9	5.7	4.3	3.9	5.6	6.3	5.9	4.6	4.5	5.1	6.4	65.1
B. Number of Days With 0.04 Inch**													
Frankfurt	9	9	9	9	9	9	10	10	9	9	9	11	112
Kassel	10	9	9	9	9	10	11	11	10	10	9	11	118
Hof	11	9	10	10	10	11	12	12	10	9	9	11	124
Nuremberg	9	8	9	9	10	10	11	11	9	8	8	10	112
Brocken	18	14	15	15	13	14	15	15	14	15	16	17	181
C. Maximum Monthly and Annual Falling Within 24 Hours (in inches)*													
Frankfurt	1.3	0.7	0.6	1.1	2.2	2.6	1.5	1.7	1.4	1.4	1.3	0.9	2.6
Kassel	0.8	1.2	0.7	1.2	0.9	2.1	1.9	1.5	1.3	1.0	1.6	0.7	2.1
Hof	0.7	0.6	0.6	2.7	1.4	1.4	2.0	1.2	1.4	1.0	1.7	1.1	2.7
Nuremberg	0.7	0.6	0.7	1.2	1.4	1.8	1.1	1.9	1.0	0.8	1.5	0.6	1.9
Brocken	2.0	3.1	2.5	2.2	2.2	3.3	2.8	2.5	5.3	1.9	2.6	2.1	5.3

*1 inch = 2.54 cm

**0.04 inch = 0.1 cm

III. TEMPERATURE AND DEW POINT

A. Variation

Temperature depends strongly upon altitude in the mountainous regions of both East and West Germany. Standard data tabulations from the Meteorological Office of Great Britain [14] illustrate this. Kassel (51°19'N, 9°29'E, 200 m) and Leipzig (51°18'N, 12°23'E, 125 m) are at almost the same latitude and are at relatively low elevations. Both have annual average daily maximum and minimum temperatures of 55 °F and 41 °F. These can be compared with the higher stations Hof (50°19'N, 11°55'E, 477 m) and Brocken (51°48'N, 10°37'E, 1150 m) which have longitudes between those of Kassel and Leipzig. Hof is one degree of latitude further south than Kassel and Leipzig, but it has the lower annual average daily maximum and minimum temperatures of 53 °F and 35 °F. Brocken is one half degree of latitude further north and much higher than Kassel and Leipzig. The annual average daily maximum and minimum temperatures at Brocken are 41 °F and 31 °F.

According to Landsberg [20], the average decrease of temperature with station elevation is 0.5 °C per 100 m (0.9 °F per 100 m). This rate of decrease for mountainous areas of the world up to 4000 m is reasonably close to the German data. Vertical changes are usually larger than this average in summer and smaller in winter. The values are lower in winter because temperature inversions are much more common in winter.

The highest peaks near Fulda are Wasserkuppe (950 m), Kreuzberg (928 m), and Vogelsberg (774 m).

Differences in mean temperature at different elevations are associated with different numbers of days with high maximum temperature. In a representative area of the central mountainous region of the German Democratic Republic, Zenker [21] finds that the number of days per year with maximum temperature greater than or equal to 25 °C (77 °F) is 35 days at 100 m, 17 days at 400 m, and 2 days at 1000 m.

Changes in temperature with distance have a noticeable effect on the environment at some time of the year. This is demonstrated in Schnelle's [22] extensive examination of data from phenological gardens in Europe. The beginning of spring can be described in terms of sprouting or blossoming of different plants. Schnelle's study shows that the beginning of spring is typically delayed 2 1/2 to 3 1/2 days per 100 m elevation with a usual range form 1 1/2 to 6 1/2 days per 100 m. This compares with an expected delay of 1 to 4 days per 100 km in the direction from south to north.

B. Statistics for Fulda

Monthly mean temperatures and dew points for three-hourly periods from 0600 CET to 1700 CET at Fulda are listed in Table 37. This table also includes standard deviations.

The diurnal variation of temperature is much smaller during cooler months than during the warmer part of the year. In December the mean temperatures are 32.3 °F for 0600–0800 CET and 35.1 °F for 1500–1700 CET. The corresponding temperatures in August are 54.9 °F and 70.2 °F.

The annual variation of temperature in the early morning hours is smaller than it is in the afternoon hours. The lowest and highest monthly mean temperatures for 0600-0800 CET are 30.3 °F for January and 56.2 °F for July. The lowest and highest monthly means for 1500-1700 CET are 34.2 °F for January and 70.2 °F for August.

Diurnal behavior of standard deviation of temperature fluctuates considerably throughout the year. Standard deviations in December and January at 1500-1700 CET are approximately 2 °F smaller than they are at 0600-0800 CET. Standard deviations in November and February are a fraction of a degree smaller in the afternoon than in the morning. Standard deviations of temperature are larger in the afternoon than in the morning from March through October. The largest standard deviation for 1500-1700 CET is 9.63 °F in May, and the smallest is 6.48 °F in February. The largest standard deviation for 0600-0800 CET is 9.56 °F in January, and the smallest is 4.79 °F in July. The diurnal range of standard deviation of temperature is largest in July when the standard deviation reaches 8.66 °F in the 1500-1700 CET time period.

Diurnal variation of dew point is small, and seasonal variation is large. For the 0600-0800 CET period, the lowest and highest monthly mean dew points are 28.0 °F in January and 51.6 °F in July. The largest diurnal range of mean dew point in Table 37 is 3.1 °F and occurs in both February and September. The smallest diurnal range of dew point is 1.0 °F and occurs in July.

Standard deviations of dew point are smallest in July and largest in winter and early spring. The standard deviations in July and December are 4.76 °F and 9.00 °F for 0600-0800 CET and 5.44 °F and 7.16 °F for 1500-1700 CET. Dirunal variation of standard deviation of dew point is smaller in the warmer months than in the winter months. In December, January, and February, standard deviations of dew point are considerably larger in the morning than in the afternoon. In May through October, standard deviations of dew point are either approximately the same in the morning and afternoon or are larger in the afternoon. The magnitude of the diurnal change of standard deviation is larger in the three winter months than in any other month.

C. Dew Point and Visibility

The dew point is the temperature to which air must be cooled at constant pressure and constant water vapor content in order to become saturated [3]. It follows that dew point indicates the amount of water vapor in the air. When atmospheric processes cause air to continue to cool after saturation is reached, some water vapor condenses on condensation nuclei. Small drops of water in the atmosphere lower visibility.

Tables 38 through 53 are contingency tables of dew point and visibility during the years 1968 to 1977. Each table is based on hourly observations for three different hours during a season. The record of surface data at Fulda was obtained on magnetic tape from the Environmental Technical Applications Center (ETAC) of the U.S. Air Force.

Table 38 shows that low dew points are more common in fog than in very clear air in winter from 0600 CET to 0800 CET. During these hours, 9.0 percent of visibilities below 1.0 km are associated with dew points less than 0 °F. Dew points below 0 °F do not occur with visibilities greater than 20 km and occur only 1.0 percent of the time with visibilities between 10 km and 20 km. Dew points above 34 °F occur 8.5 percent of the time in fog and 25.3 percent of the time with visibilities greater than 10 km.

Tables 39 through 41 show that low dew points are associated with low visibilities at later hours in winter at Fulda. At 0900-1100 CET in winter, 7.4 percent of dew points in fog are below 5 °F and 2.5 percent are above 39 °F. When visibility is above 20 km during these same hours, all dew points are at least 5 °F and 13.7 percent are above 39 °F. The highest dew points are also associated with very high visibilities from 1200 CET to 1700 CET, but very low dew points are most likely to occur with visibilities between 1.0 km and 4 km during these hours in winter. At 1200-1400 CET, the percentages of observations with dew points below 10 °F are 9.5 percent for 1.0-2.0 km visibility, 6.5 percent for 2.0-4.0 km visibility, 1.9 percent for visibility greater than 10 km, and 1.7 percent for fog. The corresponding percents at 1500-1700 CET are 7.0 percent, 5.3 percent, 2.0 percent, and 0.0 percent.

Tables 42 through 45 show that dew points at Fulda are generally higher in spring than in winter throughout the range of visibilities and throughout the day. Variation of the percentage of very high dew points as a function of visibility is much smaller in spring than in winter. In the morning very low dew points are associated with low visibilities in both seasons. In the afternoon there is little fog in spring at Fulda.

Tables 46 through 49 are contingency tables of dew point and visibility for Fulda in summer. All dew points are greater than 24 °F and less than 70 °F in summer. Low dew points are associated with high visibilities in summer, and this effect is particularly large in the afternoon. When the atmosphere is so clear in summer at Fulda that visibility is greater than 20 km, dew points below 40 °F occur 4.0 percent of the time at 1500-1700 CET, 4.4 percent at 1200-1400 CET, 4.1 percent at 0900-1100 CET, and 4.2 percent of 0600-0800 CET. Dew points below 40 °F occur only if visibility is greater than 20 km from 1200 CET to 1700 CET and only if visibility is greater than 10 km from 0900 CET to 1100 CET in summer. Sporadic observations of dew points in the 35-39 °F category occur from 0600 CET to 0800 CET when visibility is below 10 km in summer.

The diurnal variation of the relationship between dew point and visibility in fall at Fulda is shown in Tables 50 through 53. The range of dew points in fall is large in moderate and thicker fogs in the morning, but these fogs have a small range of dew point in the afternoon. The range of dew point for visibility less than or equal to 500 m is 5-64 °F during 0600-0800 CET and 0900-1100 CET. This range in heavier fogs is 25-49 °F during 1200-1400 CET and 25-54 °F during 1500-1700 CET. The diurnal change in the distribution of dew point is not so large for higher visibilities in fall, but there is some shift of the distributions toward higher dew points.

TABLE 37. Temperature and Dew Point at Fulda from the Revised Uniform Summary of Surface Weather Observations for 1973-1981

Element* / Time (CET)	Month J	F	M	A	M	J	J	A	S	O	N	D
T												
06-08	30.3	30.6	36.7	38.3	47.6	54.4	56.2	54.9	50.8	43.1	37.5	32.3
09-11	30.8	32.2	39.9	44.7	55.1	61.3	62.7	63.0	56.9	46.5	38.7	33.6
12-14	33.6	36.2	44.5	49.7	59.3	65.2	66.9	68.4	62.7	51.4	41.1	35.6
15-17	34.2	37.5	45.5	51.2	60.5	66.7	68.9	70.2	64.0	51.8	41.2	35.1
DP												
06-08	28.0	28.4	33.6	34.0	42.1	49.6	51.6	51.5	48.1	40.6	34.2	29.9
09-11	28.0	29.4	34.9	36.0	43.6	50.7	52.6	53.8	50.3	41.7	34.5	30.7
12-14	29.6	31.1	35.9	36.4	43.8	50.4	52.0	53.6	51.0	43.0	35.4	31.6
15-17	30.2	31.5	36.0	36.4	44.1	50.4	52.0	53.4	51.2	43.0	35.9	31.2
σ(T)												
06-08	9.56	7.39	7.38	6.16	6.69	5.88	4.79	5.45	6.28	6.27	7.59	9.26
09-11	9.23	7.32	7.22	7.42	8.14	7.70	6.97	6.75	6.69	6.71	7.44	8.70
12-14	7.82	6.75	8.06	9.21	9.04	8.96	8.20	7.69	7.53	7.46	7.24	7.64
15-17	7.28	6.48	8.83	9.57	9.63	9.07	8.66	7.97	7.85	7.85	7.01	7.40
σ(DP)												
06-08	8.87	7.06	7.33	6.31	6.77	5.92	4.76	5.37	5.91	6.34	7.46	9.00
09-11	8.68	6.80	7.03	6.33	7.03	6.18	5.32	4.90	5.81	6.43	6.96	8.42
12-14	7.38	5.91	7.26	6.85	6.87	6.20	5.45	5.69	6.04	6.14	6.62	7.55
15-17	7.04	5.43	7.53	6.79	6.54	6.14	5.44	5.96	6.00	6.25	6.37	7.16

*T = Temperature in Degrees Fahrenheit.
DP = Dew Point in Degrees Fahrenheit.
σ(T) = Standard Deviation of Temperature in Degrees Fahrenheit.
σ(DP) = Standard Deviation of Dew Point in Degrees Fahrenheit.

TABLE 38. Relationship Between Dew Point and Visibility at Fulda from 0600 to 0800 CET in Winter

Dew Point (°F)	Visibility (kilometers)								
	≤0.2	>0.2 and ≤0.5	>0.5 and ≤1.0	>1.0 and ≤2.0	>2.0 and ≤4.0	>4.0 and ≤10	>10 and ≤20	>20	Total
<00	7	6	6	10	17	8	5	0	59
00-04	1	0	1	8	5	29	3	5	52
05-09	3	2	5	13	28	24	10	18	103
10-14	10	7	8	19	49	53	8	12	166
15-19	9	5	4	21	59	69	43	21	231
20-24	15	8	11	38	76	106	48	27	329
25-29	12	8	19	66	67	141	104	51	468
30-34	22	10	14	55	97	224	148	96	666
35-39	7	4	5	22	31	84	79	36	268
40-44	2	0	0	3	10	31	47	26	119
45-49	0	0	0	0	1	11	15	0	27
50-54	0	0	0	0	2	3	0	0	5
≥55	0	0	0	0	0	0	0	0	0
Total	88	50	73	255	442	783	510	292	2493

TABLE 39. Relationship Between Dew Point and Visibility at Fulda from 0900 to 1100 CET in Winter

Dew Point (°F)	Visibility (kilometers)								
	≤0.2	>0.2 and ≤0.5	>0.5 and ≤1.0	>1.0 and ≤2.0	>2.0 and ≤4.0	>4.0 and ≤10	>10 and ≤20	>20	Total
<00	4	1	3	9	6	7	2	0	32
00-04	1	3	6	13	14	13	4	0	54
05-09	3	0	3	24	25	25	6	10	96
10-14	9	2	11	20	54	34	13	5	148
15-19	6	5	6	51	85	86	30	10	279
20-24	17	14	13	37	86	84	52	32	335
25-29	6	7	27	64	78	104	100	48	434
30-34	24	11	37	82	126	200	149	86	715
35-39	7	3	7	21	45	90	102	68	343
40-44	2	3	0	4	8	40	39	36	132
45-49	0	0	1	0	0	12	10	4	27
50-54	0	0	0	0	0	1	3	1	5
≥55	0	0	0	0	0	0	0	0	0
Total	79	49	114	325	527	696	510	300	2600

TABLE 40. Relationship Between Dew Point and Visibility at Fulda from 1200 to 1400 CET in Winter

Dew Point (°F)	Visibility (kilometers)								
	≤0.2	>0.2 and ≤0.5	>0.5 and ≤1.0	>1.0 and ≤2.0	>2.0 and ≤4.0	>4.0 and ≤10	>10 and ≤20	>20	Total
<00	0	0	1	2	1	0	0	0	4
00-04	0	0	0	3	6	10	1	0	20
05-09	1	0	0	17	22	19	7	10	76
10-14	0	3	1	14	37	29	8	11	103
15-19	0	4	7	31	52	68	40	17	219
20-24	3	4	12	39	75	121	57	36	347
25-29	3	11	14	49	107	134	99	80	497
30-34	9	9	23	60	89	227	138	116	671
35-39	3	4	4	13	42	112	123	80	381
40-44	0	0	1	4	18	45	39	49	156
45-49	0	0	0	0	0	13	10	10	33
50-54	0	0	0	0	0	1	4	1	6
≥55	0	0	0	0	0	0	0	0	0
Total	19	35	63	232	449	779	526	410	2513

TABLE 41. Relationship Between Dew Point and Visibility at Fulda from 1500 to 1700 CET in Winter

Dew Point (°F)	Visibility (kilometers)								
	≤0.2	>0.2 and ≤0.5	>0.5 and ≤1.0	>1.0 and ≤2.0	>2.0 and ≤4.0	>4.0 and ≤10	>10 and ≤20	>20	Total
<00	0	0	0	2	0	0	1	0	3
00-04	0	0	0	1	4	5	1	0	11
05-09	0	0	0	11	17	16	2	15	61
10-14	0	0	0	9	35	27	17	14	102
15-19	1	1	7	17	46	75	38	25	207
20-24	1	2	10	36	71	123	53	53	349
25-29	5	8	9	50	79	112	103	79	445
30-34	6	9	20	58	89	191	154	148	675
35-39	6	7	5	13	40	143	98	71	378
40-44	1	0	0	3	8	39	33	45	129
45-49	0	0	0	0	4	28	11	2	45
50-54	0	0	0	0	1	3	2	0	6
≥55	0	0	0	0	0	0	0	0	0
Total	20	22	51	200	394	762	510	452	2411

TABLE 42. Relationship Between Dew Point and Visibility at Fulda from 0600 to 0800 CET in Spring

Dew Point (°F)	Visibility (kilometers)								
	≤0.2	>0.2 and ≤0.5	>0.5 and ≤1.0	>1.0 and ≤2.0	>2.0 and ≤4.0	>4.0 and ≤10	>10 and ≤20	>20	Total
<00	3	4	0	1	0	0	0	0	8
00-04	1	0	0	0	0	1	2	0	4
05-09	1	1	2	0	2	1	0	1	8
10-14	1	0	0	2	2	16	2	6	29
15-19	0	0	0	6	15	22	16	10	69
20-24	2	1	5	20	24	40	21	21	134
25-29	13	5	10	18	39	60	57	54	256
30-34	33	4	9	25	67	102	98	119	457
35-39	26	9	5	17	66	147	154	102	525
40-44	25	10	12	30	55	148	162	116	558
45-49	13	8	9	27	52	98	104	78	389
50-54	8	1	2	14	16	43	37	26	146
55-59	1	1	2	5	11	4	1	6	31
≥60	0	0	0	0	0	0	0	0	0
Total	127	44	56	165	347	682	654	539	2614

TABLE 43. Relationship Between Dew Point and Visibility at Fulda from 0900 to 1100 CET in Spring

Dew Point (°F)	Visibility (kilometers)								
	≤0.2	>0.2 and ≤0.5	>0.5 and ≤1.0	>1.0 and ≤2.0	>2.0 and ≤4.0	>4.0 and ≤10	>10 and ≤20	>20	Total
<00	0	0	0	0	0	0	0	0	0
00-04	1	1	1	0	1	0	0	0	4
05-09	0	0	1	3	1	1	0	0	6
10-14	0	0	1	2	4	7	1	1	16
15-19	0	1	1	2	11	12	12	3	42
20-24	0	0	2	8	35	27	27	28	127
25-29	1	2	2	20	27	54	47	83	236
30-34	15	0	1	23	41	91	100	120	391
35-39	6	3	4	10	47	126	170	143	509
40-44	2	4	4	13	43	147	187	218	618
45-49	3	2	4	9	49	141	131	110	449
50-54	1	0	2	6	12	63	53	67	204
55-59	0	0	0	3	10	19	16	14	62
60-64	0	0	0	0	1	1	0	0	2
≥65	0	0	0	0	0	0	0	0	0
Total	29	13	23	99	282	689	744	787	2666

TABLE 44. Relationship Between Dew Point and Visibility at Fulda from 1200 to 1400 CET in Spring

Dew Point (°F)	Visibility (kilometers)								
	≤0.2	>0.2 and ≤0.5	>0.5 and ≤1.0	>1.0 and ≤2.0	>2.0 and ≤4.0	>4.0 and ≤10	>10 and ≤20	>20	Total
<04	0	0	0	0	0	0	0	0	0
05-09	0	0	0	0	0	0	0	1	1
10-14	0	0	0	1	1	6	3	3	14
15-19	0	0	0	4	1	6	13	3	27
20-24	0	0	0	1	10	34	24	42	111
25-29	0	0	0	10	22	59	32	154	277
30-34	0	0	2	9	22	55	80	203	371
35-39	0	0	0	7	22	105	177	248	559
40-44	0	0	0	2	15	104	186	274	581
45-49	0	0	0	3	10	88	157	179	437
50-54	0	0	0	2	7	62	65	64	200
55-59	0	0	0	0	3	18	20	14	55
60-64	0	0	0	0	0	2	0	0	2
≥65	0	0	0	0	0	0	0	0	0
Total	0	0	2	39	113	539	757	1185	2635

TABLE 45. Relationship Between Dew Point and Visibility at Fulda from 1500 to 1700 CET in Spring

Dew Point (°F)	Visibility (kilometers)								
	≤0.2	>0.2 and ≤0.5	>0.5 and ≤1.0	>1.0 and ≤2.0	>2.0 and ≤4.0	>4.0 and ≤10	>10 and ≤20	>20	Total
<04	0	0	0	0	0	0	0	0	0
05-09	0	0	0	0	0	0	0	1	1
10-14	0	0	0	0	0	5	0	4	9
15-19	0	0	0	0	0	9	10	10	29
20-24	0	0	0	2	7	24	20	68	121
25-29	0	0	1	5	15	55	34	131	241
30-34	0	0	2	4	23	56	61	239	385
35-39	0	0	0	3	9	76	158	324	570
40-44	0	0	1	1	10	69	189	345	615
45-49	0	0	0	0	6	57	132	157	352
50-54	0	0	0	2	5	35	69	61	172
55-59	0	0	0	0	2	14	16	17	49
60-64	0	0	0	0	0	2	2	1	5
≥65	0	0	0	0	0	0	0	0	0
Total	0	0	4	17	77	402	691	1358	2549

TABLE 46. Relationship Between Dew Point and Visibility at Fulda from 0600 to 0800 CET in Summer

Dew Point (°F)	Visibility (kilometers)								
	≤0.2	>0.2 and ≤0.5	>0.5 and ≤1.0	>1.0 and ≤2.0	>2.0 and ≤4.0	>4.0 and ≤10	>10 and ≤20	>20	Total
<29	0	0	0	0	0	0	0	0	0
30-34	0	0	0	0	0	0	2	5	7
35-39	0	0	1	1	2	1	11	21	37
40-44	17	3	4	5	9	27	78	61	204
45-49	43	12	12	20	45	131	213	172	648
50-54	49	15	13	32	73	240	226	206	854
55-59	23	18	24	48	133	196	116	128	686
60-64	8	1	4	14	29	50	41	33	180
65-69	1	0	1	7	2	1	0	0	12
≥70	0	0	0	0	0	0	0	0	0
Total	141	49	59	127	293	646	687	626	2628

TABLE 47. Relationship Between Dew Point and Visibility at Fulda from 0900 to 1100 CET in Summer

Dew Point (°F)	Visibility (kilometers)								
	≤0.2	>0.2 and ≤0.5	>0.5 and ≤1.0	>1.0 and ≤2.0	>2.0 and ≤4.0	>4.0 and ≤10	>10 and ≤20	>20	Total
<24	0	0	0	0	0	0	0	0	0
25-29	0	0	0	0	0	0	0	1	1
30-34	0	0	0	0	0	0	0	10	10
35-39	0	0	0	0	0	0	3	34	37
40-44	0	0	0	0	2	2	39	120	163
45-49	1	2	1	2	6	53	184	285	534
50-54	0	5	4	7	34	160	280	355	845
55-59	1	3	6	11	49	216	236	218	740
60-64	0	0	2	7	25	129	101	67	331
65-69	0	0	0	0	5	9	4	6	24
≥70	0	0	0	0	0	0	0	0	0
Total	2	10	13	27	121	569	847	1096	2685

TABLE 48. Relationship Between Dew Point and Visibility at Fulda from 1200 to 1400 CET in Summer

Dew Point (°F)	Visibility (kilometers)								
	≤0.2	>0.2 and ≤0.5	>0.5 and ≤1.0	>1.0 and ≤2.0	>2.0 and ≤4.0	>4.0 and ≤10	>10 and ≤20	>20	Total
<24	0	0	0	0	0	0	0	0	0
25-29	0	0	0	0	0	0	0	2	2
30-34	0	0	0	0	0	0	0	19	19
35-39	0	0	0	0	0	0	0	52	52
40-44	0	0	0	0	0	4	23	209	236
45-49	1	0	0	0	0	18	113	440	572
50-54	0	0	0	0	2	67	291	497	857
55-59	0	1	0	1	14	91	227	338	672
60-64	0	0	0	0	4	62	80	80	226
65-69	0	0	0	0	3	6	11	8	28
≥70	0	0	0	0	0	0	0	0	0
Total	1	1	0	1	23	248	745	1645	2664

TABLE 49. Relationship Between Dew Point and Visibility at Fulda from 1500 to 1700 CET in Summer

Dew Point (°F)	Visibility (kilometers)								
	≤0.2	>0.2 and ≤0.5	>0.5 and ≤1.0	>1.0 and ≤2.0	>2.0 and ≤4.0	>4.0 and ≤10	>10 and ≤20	>20	Total
<24	0	0	0	0	0	0	0	0	0
25-29	0	0	0	0	0	0	0	1	1
30-34	0	0	0	0	0	0	0	10	10
35-39	0	0	0	0	0	0	0	60	60
40-44	0	0	0	0	0	1	13	217	231
45-49	0	0	0	0	0	9	93	477	579
50-54	0	0	0	0	3	47	243	544	837
55-59	0	0	0	0	6	61	188	371	626
60-64	0	0	0	3	3	36	68	96	206
65-69	0	0	0	0	1	0	14	5	20
≥70	0	0	0	0	0	0	0	0	0
Total	0	0	0	3	13	154	619	1781	2570

TABLE 50. Relationship Between Dew Point and Visibility at Fulda from 0600 to 0800 CET in Fall

Dew Point (°F)	Visibility (kilometers)								
	≤0.2	>0.2 and ≤0.5	>0.5 and ≤1.0	>1.0 and ≤2.0	>2.0 and ≤4.0	>4.0 and ≤10	>10 and ≤20	>20	Total
<04	0	0	0	0	0	0	0	0	0
05-09	1	0	1	0	1	0	0	0	3
10-14	1	0	0	0	1	2	0	1	5
15-19	0	0	0	0	2	5	3	4	14
20-24	11	0	5	5	9	16	6	2	54
25-29	50	6	10	14	16	35	21	17	169
30-34	73	7	10	30	37	88	50	48	343
35-39	108	13	14	14	46	86	73	67	421
40-44	99	29	20	27	40	108	106	80	509
45-49	103	22	14	20	46	140	90	94	529
50-54	36	22	13	19	31	99	66	84	370
55-59	12	3	10	11	36	36	39	14	161
60-64	3	0	0	0	0	3	3	2	11
≥65	0	0	0	0	0	0	0	0	0
Total	497	102	97	140	265	618	457	413	2589

TABLE 51. Relationship Between Dew Point and Visibility at Fulda from 0900 to 1100 CET in Fall

Dew Point (°F)	Visibility (kilometers)								
	≤0.2	>0.2 and ≤0.5	>0.5 and ≤1.0	>1.0 and ≤2.0	>2.0 and ≤4.0	>4.0 and ≤10	>10 and ≤20	>20	Total
<04	0	0	0	0	0	0	0	0	0
05-09	0	2	0	0	0	0	0	0	2
10-14	0	0	0	1	1	1	0	1	4
15-19	0	0	0	0	2	1	1	3	7
20-24	6	1	0	1	13	14	7	2	44
25-29	32	3	6	10	18	32	15	24	140
30-34	51	5	11	21	53	73	41	36	291
35-39	49	15	11	18	53	104	92	85	427
40-44	46	18	27	26	50	130	132	104	533
45-49	25	20	8	29	63	138	152	98	533
50-54	18	6	17	28	77	128	130	128	532
55-59	6	2	7	17	45	63	54	30	224
60-64	1	1	2	5	6	18	14	11	58
65-69	0	0	0	0	1	0	0	0	1
≥70	0	0	0	0	0	0	0	0	0
Total	234	73	89	156	382	702	638	622	2796

TABLE 52. Relationship Between Dew Point and Visibility at Fulda from 1200 to 1400 CET in Fall

Dew Point (°F)	Visibility (kilometers)								
	≤0.2	>0.2 and ≤0.5	>0.5 and ≤1.0	>1.0 and ≤2.0	>2.0 and ≤4.0	>4.0 and ≤10	>10 and ≤20	>20	Total
<14	0	0	0	0	0	0	0	0	0
15-19	0	0	0	0	0	3	0	2	5
20-24	0	0	0	0	5	10	10	9	34
25-29	4	0	1	6	17	35	13	15	91
30-34	17	2	13	14	31	83	45	53	258
35-39	8	0	7	11	33	90	80	127	356
40-44	3	3	6	15	38	138	158	203	564
45-49	1	4	1	9	38	148	163	198	562
50-54	0	0	3	4	36	118	167	213	541
55-59	0	0	0	1	31	85	60	71	248
60-64	0	0	0	3	7	15	14	19	58
65-69	0	0	0	0	0	7	0	0	7
≥70	0	0	0	0	0	0	0	0	0
Total	33	9	31	63	236	732	710	910	2724

TABLE 53. Relationship Between Dew Point and Visibility at Fulda from 1500 to 1700 CET in Fall

Dew Point (°F)	Visibility (kilometers)								
	≤0.2	>0.2 and ≤0.5	>0.5 and ≤1.0	>1.0 and ≤2.0	>2.0 and ≤4.0	>4.0 and ≤10	>10 and ≤20	>20	Total
<14	0	0	0	0	0	0	0	0	0
15-19	0	0	0	0	0	1	4	0	5
20-24	0	0	2	2	1	7	8	3	23
25-29	3	0	2	4	10	32	17	20	88
30-34	13	4	8	12	32	95	39	55	258
35-39	7	4	6	8	42	65	92	154	378
40-44	0	2	2	10	22	100	139	242	517
45-49	1	2	1	8	27	115	142	221	517
50-54	1	0	1	6	24	87	159	231	508
55-59	0	0	1	5	14	71	66	98	255
60-64	0	0	0	1	1	16	17	19	54
65-69	0	0	0	0	0	7	3	0	10
≥70	0	0	0	0	0	0	0	0	0
Total	25	12	23	55	173	596	686	1043	2613

IV. WIND

A. Surface Velocity

Both the magnitude and the direction of the horizontal wind vector vary with space and time. Diurnal and seasonal variations are important in the Fulda area just as they are throughout the middle latitudes. Spatial variations in this area are often particularly large because of the uneven terrain.

1. Fulda Data

Figures 3 through 6 show the monthly mean speeds for different times of day from 0600 CET to 1700 CET at Fulda according to the RUSSWO [13] data for 1973-1981. Mean diurnal fluctuations are greater than 4.0 knots in April, May, August, and September. The diurnal variation is largest in August when the mean speed is 1.7 knots at 0600-0800 CET and 6.4 knots at 1500-1700 CET. Lowest mean speeds occur at 0600-0800 CET throughout the year, and seasonal variations are largest in these early morning hours. At 0600-0800 CET, the monthly mean speeds in August and December differ by more than a factor of 3. During the later morning hours and in the afternoon, the largest and smallest monthly mean speeds differ by less than a factor of 2.

The mean speed as a function of the direction from which the wind blows at Fulda is shown in Table 54 for each month at 0600-0800 CET. Directions are expressed as 16 points of the compass, i.e., there are 3 intermediate points between cardinal points. Winds are called variable when the direction fluctuates so rapidly and so widely that a prevailing direction on the scale of standard meteorological surface data cannot be determined. Weakest winds generally blow from a direction within the interval from east to south. Strongest winds occur with variable direction. The strongest of winds with a defined direction at 0600-0800 CET are within the interval from southwest to west during most of the year. Relatively high speeds also occur between ENE and NNE. In May at 0600-0800 CET, the mean speed of winds blowing from ENE is higher than the mean of winds blowing from any of the other 15 directions.

Tables 55 through 57 are similar to Table 54 but are for later in the day. Many monthly mean speeds for variable winds are slightly lower in the afternoon than in the early morning. Most monthly means for the 16 points of the compass become larger as the sun moves higher in the sky. The largest diurnal variation of speed is in the warmer part of the year for winds blowing from directions between east and south. The best examples occur for ESE in April and June when both means at 0600-0800 CET are 1.3 knots, but the means at 1200-1400 CET are 6.4 knots and 4.4 knots, respectively. Winds with northerly and westerly components generally do not double in strength between early morning and afternoon.

Tables 58 through 61 contain frequencies of winds blowing from different directions for each month at different times of day at Fulda. Sums of percents in columns may deviate from 100.0 because of rounding. At 0600-0800 CET, calms occur at least one-fifth of the time throughout the year, and the wind is calm more than half of these early hours in August and September. Winds at Fulda in the afternoon are calm less than 10 percent of the time from

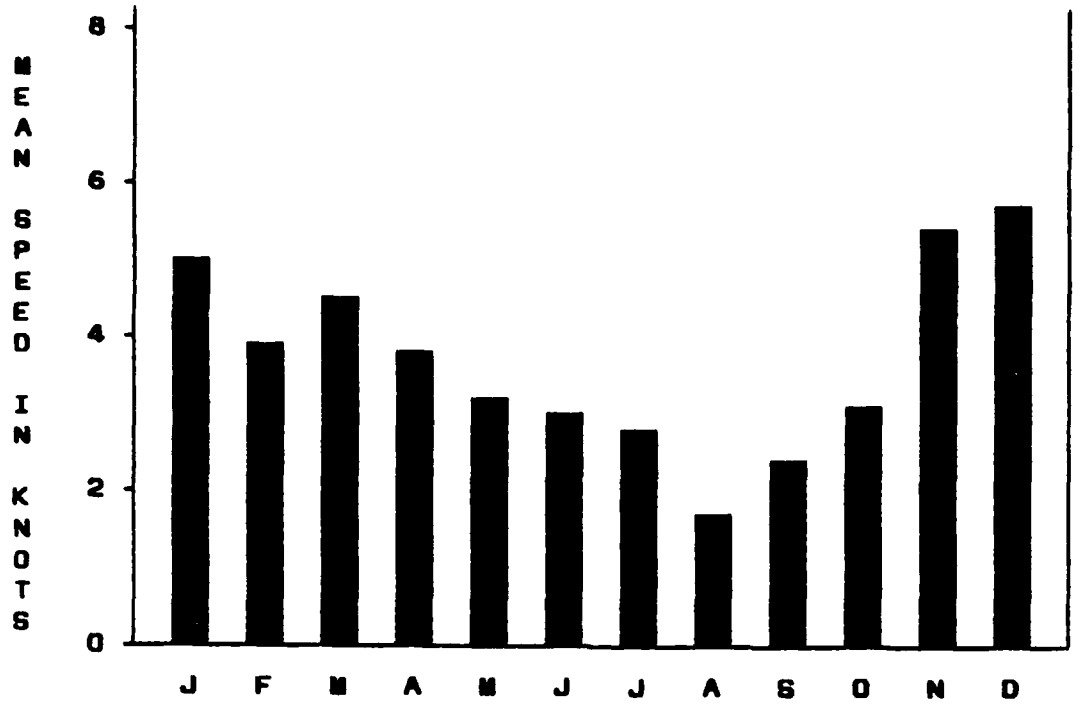

Figure 3. Monthly variation of wind speed (knots) at Fulda during 0600-0800 CET.

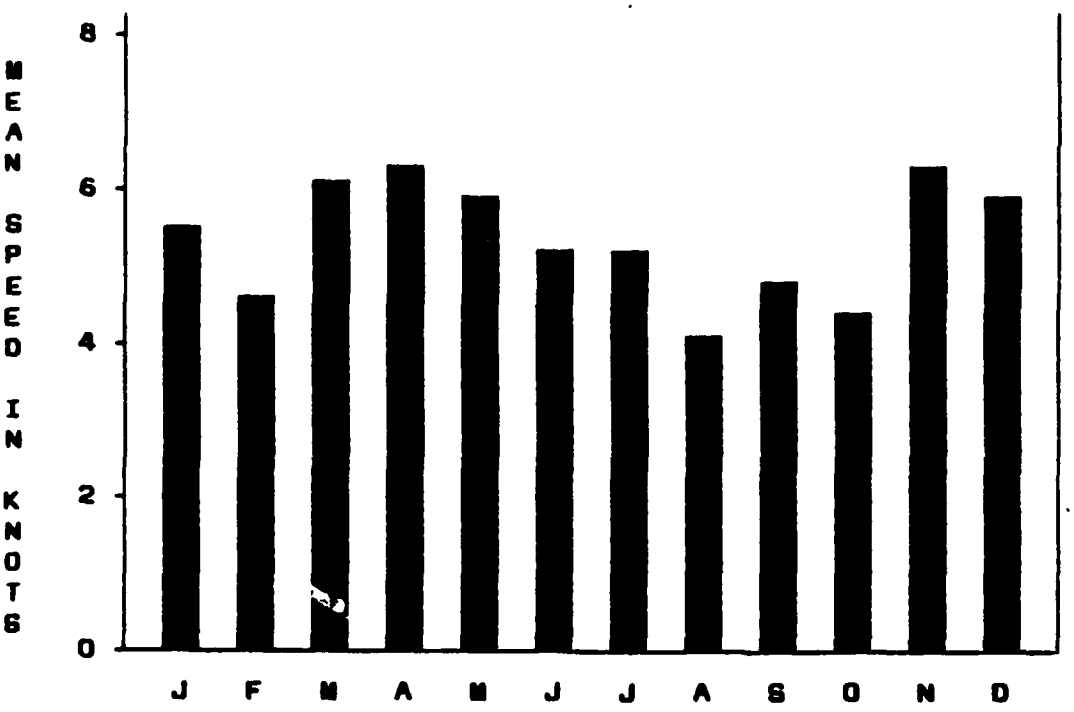

Figure 4. Monthly variation of wind speed (knots) at Fulda during 0900-1100 CET.

Figure 5. Monthly variation of wind speed (knots) at Fulda during 1200-1400 CET.

Figure 6. Monthly variation of wind speed (knots) at Fulda during 1500-1700 CET.

TABLE 54. Relationship of Speed (knots) and Direction of Surface Wind at Fulda for 0600-0800 CET During 1973-1981

Direction	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
North	4.5	4.3	4.4	5.4	3.8	3.8	3.5	3.3	3.1	4.6	3.9	5.5
NNE	6.9	7.2	6.2	5.6	6.7	4.7	5.0	4.3	3.9	5.3	6.2	6.3
NE	5.0	6.0	7.8	6.3	7.9	4.5	*	3.8	4.0	5.3	6.2	*
ENE	5.0	5.2	7.5	7.0	8.7	4.5	*	2.0	2.5	4.0	8.7	4.5
East	3.3	6.2	4.7	2.0	4.0	2.0	3.3	3.5	2.0	8.0	4.0	3.3
ESE	3.2	3.8	2.5	1.3	3.5	1.3	2.7	1.8	2.4	4.8	1.0	4.9
SE	3.3	1.9	2.8	2.7	3.7	3.0	2.0	2.5	2.3	3.2	3.3	4.1
SSE	4.1	3.0	3.0	2.3	3.7	2.8	2.4	2.0	2.0	3.6	4.5	4.4
South	5.6	4.9	6.1	4.4	4.5	4.1	4.0	3.5	5.0	4.7	5.2	5.5
SSW	7.1	6.1	7.0	6.7	5.5	5.8	5.3	4.4	6.3	6.2	7.1	6.4
SW	8.3	7.9	7.3	7.9	7.9	6.6	5.8	6.0	6.6	6.8	8.7	9.9
WSW	8.6	7.7	9.1	5.5	6.2	7.1	6.2	6.2	5.4	8.5	9.1	10.4
West	10.9	9.1	9.1	10.0	5.6	5.0	6.4	5.2	6.4	7.0	8.3	9.6
WNW	8.0	8.2	4.6	6.3	4.4	5.3	5.8	4.3	6.5	4.8	6.5	8.4
NW	6.4	3.9	5.0	5.8	4.7	6.1	4.3	3.8	3.5	3.5	4.9	7.6
NNW	6.8	3.7	4.2	4.8	3.4	4.2	3.6	2.9	3.0	4.0	4.4	4.9
Variable	11.2	10.7	10.4	11.3	9.5	8.6	7.0	*	*	*	14.6	11.3

*No observations

TABLE 55. Relationship of Speed (knots) and Direction of Surface Wind at Fulda for 0900-1100 CET During 1973-1981

Direction	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
North	5.1	4.2	4.7	5.9	4.7	4.2	4.3	4.0	3.4	5.4	4.9	4.3
NNE	7.4	7.0	7.1	7.3	6.2	4.7	3.7	4.0	5.1	3.8	6.5	7.8
NE	5.4	5.8	10.0	7.7	7.0	4.7	5.9	4.7	6.6	5.4	9.3	5.3
ENE	5.0	8.4	7.0	9.0	8.5	5.8	4.6	4.1	2.9	4.6	7.0	2.3
East	4.0	5.0	5.9	4.3	8.1	3.9	3.2	4.0	1.5	6.5	8.0	4.3
ESE	2.9	4.5	2.9	5.9	6.8	3.3	4.0	5.1	2.3	4.7	5.3	3.5
SE	3.5	4.7	2.1	5.8	4.9	1.3	3.8	5.7	3.3	6.5	3.3	4.2
SSE	5.1	3.9	3.6	6.2	5.6	3.7	4.2	4.3	4.1	5.0	3.6	3.4
South	6.3	5.8	6.2	4.8	6.0	5.5	5.9	5.2	6.4	5.4	5.1	6.3
SSW	7.8	6.8	7.8	7.6	6.0	6.7	6.7	5.9	7.6	6.6	7.6	6.7
SW	8.6	8.6	10.4	9.1	8.2	8.6	7.3	6.7	8.3	8.8	9.7	8.5
WSW	9.8	9.7	9.6	10.6	8.0	7.9	7.5	7.6	8.4	9.9	9.3	10.8
West	11.2	8.8	9.7	9.5	8.6	7.6	6.8	7.5	9.0	7.6	10.3	10.0
WNW	7.8	6.0	7.4	7.8	5.9	6.7	6.8	7.1	7.0	6.6	7.3	7.2
NW	7.2	3.8	5.9	7.2	5.6	7.6	6.8	6.2	6.4	7.0	5.4	7.3
NNW	5.8	4.5	6.0	5.3	4.7	5.6	5.0	3.8	4.3	3.6	5.4	4.6
Variable	11.4	9.4	10.6	10.4	9.8	8.4	8.0	8.1	9.6	9.5	12.0	15.3

TABLE 56. Relationship of Speed (knots) and Direction of Surface Wind at Fulda for 1200-1400 CET During 1973-1981

Direction	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
North	5.5	4.8	5.2	7.6	6.5	6.8	5.4	5.0	4.2	5.6	5.4	5.4
NNE	7.0	7.1	7.1	7.4	7.2	5.5	5.7	5.6	5.8	5.8	6.4	6.9
NE	8.3	7.6	7.9	8.3	7.9	5.6	4.9	5.7	5.6	5.9	8.7	6.5
ENE	5.0	8.9	8.5	7.4	9.6	6.1	3.6	5.8	5.2	5.4	7.5	6.4
East	2.3	5.6	4.5	6.2	7.3	4.9	4.5	5.8	3.8	7.1	8.0	5.7
ESE	3.6	8.1	4.6	6.4	7.0	4.4	3.9	6.0	3.6	6.8	2.8	9.0
SE	2.0	4.5	4.6	7.8	6.6	5.3	4.3	5.1	4.9	5.5	2.6	4.0
SSE	5.0	6.1	6.5	6.1	6.1	3.9	4.4	5.2	5.8	6.9	4.3	5.3
South	6.9	6.9	6.6	5.1	6.8	6.3	5.3	6.5	7.0	6.2	6.5	7.8
SSW	7.0	7.8	8.3	7.6	7.3	6.9	8.1	6.3	7.9	7.3	7.9	6.8
SW	8.9	9.0	10.2	9.9	8.7	8.6	9.0	6.8	8.8	9.8	9.4	8.8
WSW	9.9	9.7	11.2	8.8	7.6	8.7	8.2	6.7	8.3	9.9	9.7	9.9
West	11.1	9.9	10.8	9.8	8.9	7.9	7.5	8.2	8.5	9.0	9.4	9.5
WNW	10.8	7.0	10.2	9.2	7.8	8.0	6.5	7.2	7.3	8.6	9.4	9.3
NW	8.1	6.7	5.7	9.5	8.4	6.7	6.9	7.0	5.8	6.9	7.3	8.6
NNW	6.6	3.3	6.0	6.9	5.3	6.8	6.2	5.1	5.1	5.6	5.1	4.8
Variable	11.4	9.5	9.9	9.8	9.4	9.1	8.4	8.3	9.0	9.6	11.7	11.7

TABLE 57. Relationship of Speed (knots) and Direction of Surface Wind at Fulda for 1500-1700 CET During 1973-1981

Direction	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
North	6.1	5.9	5.4	8.6	5.5	6.6	6.3	5.2	5.1	5.3	6.2	5.6
NNE	5.2	7.5	7.4	7.2	6.6	5.9	4.8	6.4	5.1	6.2	5.9	6.3
NE	7.1	6.8	8.7	8.1	9.9	7.5	5.3	7.6	4.8	5.7	7.4	4.3
ENE	6.3	6.1	10.3	10.0	10.3	6.6	5.5	6.7	4.4	6.7	9.0	7.2
East	5.4	6.0	7.5	5.9	7.7	6.6	5.4	5.6	4.8	10.8	4.0	1.0
ESE	3.7	7.3	3.7	8.5	6.9	5.7	3.5	6.1	5.3	4.1	4.0	4.0
SE	4.5	5.1	6.6	6.1	4.9	3.8	3.0	5.4	6.2	5.6	2.0	9.0
SSE	4.5	6.4	7.3	5.5	6.3	4.3	4.0	5.5	5.8	5.2	5.5	3.7
South	5.9	5.3	6.7	5.0	5.7	4.6	4.3	5.3	6.8	5.2	5.0	5.8
SSW	6.9	6.5	7.4	9.1	6.7	6.6	8.1	5.5	6.4	6.0	7.3	6.4
SW	8.3	8.5	9.3	8.2	7.3	8.0	7.4	7.4	7.5	7.7	8.4	8.4
WSW	8.1	10.1	9.3	9.2	8.5	8.4	7.7	7.3	7.1	7.4	7.5	10.5
West	11.4	8.9	10.0	9.0	9.2	6.4	8.5	6.9	7.7	8.3	9.6	9.5
WNW	10.2	5.4	8.2	8.6	8.0	7.8	6.6	7.7	8.5	8.0	9.8	5.9
NW	6.6	6.1	6.4	9.5	6.6	6.5	7.1	6.8	5.9	6.3	8.5	6.9
NNW	5.4	4.0	5.3	7.5	6.2	6.1	5.9	5.2	6.0	5.3	5.3	6.6
Variable	10.3	6.6	9.6	10.4	9.7	6.6	9.2	6.6	6.9	9.0	10.9	10.2

TABLE 58. Frequency (percent) of Winds as a Function of Direction at Fulda for 0600-0800 CET During 1973-1981

Direction	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
North	3.7	4.7	7.5	10.2	9.8	7.9	5.3	7.4	4.1	3.9	2.0	3.7
NNE	2.2	5.2	4.5	4.4	5.4	3.5	0.8	1.0	1.2	1.2	1.6	2.2
NE	0.3	4.5	3.5	1.6	3.2	1.0	0.0	0.6	0.3	1.0	2.4	0.0
ENE	0.8	2.3	0.6	0.3	1.7	0.3	0.0	0.2	0.3	0.2	1.3	0.4
East	0.7	0.9	0.5	0.2	0.3	0.5	0.5	0.3	0.7	0.2	0.4	0.6
ESE	0.8	0.9	0.3	0.5	1.3	0.6	0.5	0.8	0.9	0.7	0.2	1.3
SE	2.2	1.4	1.9	1.0	1.6	1.1	1.3	2.1	1.2	1.7	0.5	1.7
SSE	4.5	3.8	1.6	1.5	1.7	1.3	1.6	1.9	1.7	3.9	2.7	3.5
South	11.7	8.3	7.9	2.8	6.2	5.1	6.2	3.2	7.3	9.8	10.4	12.9
SSW	13.4	9.4	8.9	6.0	7.0	7.1	10.1	4.8	8.7	10.2	13.5	14.8
SW	9.4	9.2	5.4	7.1	3.3	6.4	7.8	2.9	6.7	7.5	12.5	12.4
WSW	5.9	3.6	5.6	3.6	2.8	4.8	5.6	2.4	3.6	3.6	10.2	9.6
West	6.9	3.1	6.5	4.7	3.8	4.0	7.0	3.2	3.8	4.4	8.7	4.2
WNW	1.5	1.6	3.0	3.1	2.1	3.7	2.7	2.1	2.0	2.9	3.3	2.8
NW	3.2	2.3	3.5	5.0	4.6	4.5	2.6	3.6	2.6	1.7	3.5	3.1
NNW	2.2	3.2	6.2	8.6	6.5	7.9	4.3	7.0	4.3	3.7	1.8	3.7
Variable	1.7	0.5	2.1	1.0	0.9	0.8	0.2	0.0	0.0	0.0	0.9	1.1
Calm	29.0	36.1	30.5	38.6	37.9	40.5	43.6	56.7	50.9	43.5	24.2	22.1

TABLE 59. Frequency (percent) of Winds as a Function of Direction at Fulda for 0900-1100 CET During 1973-1981

Direction	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
North	3.1	4.8	6.2	9.9	6.7	9.0	7.3	6.0	5.9	5.1	2.3	2.2
NNE	2.8	6.0	5.9	6.3	6.9	5.6	2.1	5.6	3.4	1.8	2.3	3.0
NE	0.7	2.9	2.6	3.9	3.1	3.7	2.1	2.7	2.6	1.2	1.4	1.3
ENE	1.5	2.2	1.5	3.6	4.3	2.2	1.3	2.0	1.2	0.7	1.1	0.6
East	0.4	1.4	1.0	0.9	2.2	2.0	0.8	1.9	0.3	0.9	0.5	0.5
ESE	1.5	0.9	1.2	2.3	3.2	0.9	1.4	1.7	0.5	1.0	0.5	1.0
SE	2.2	2.9	1.8	0.9	2.1	0.4	0.7	1.7	1.9	1.2	0.6	1.4
SSE	3.5	3.1	1.8	1.6	3.1	2.7	1.4	3.6	2.0	3.4	2.6	3.0
South	14.2	9.3	7.6	6.0	9.5	8.0	4.3	8.0	10.8	11.7	12.0	13.9
SSW	9.7	8.7	11.3	3.9	8.1	8.6	9.9	8.9	12.7	10.8	16.0	15.3
SW	8.7	6.0	9.0	6.9	4.3	6.9	9.9	5.9	7.1	7.2	15.6	10.9
WSW	6.3	4.3	6.2	5.9	5.0	8.2	8.0	5.3	6.0	5.9	9.9	11.8
West	8.4	4.6	7.5	5.3	7.1	6.7	10.8	6.4	5.4	4.7	7.6	6.4
WNW	2.5	1.5	4.7	4.4	2.7	4.7	6.6	3.4	3.2	3.8	1.9	2.1
NW	3.1	2.8	4.7	8.3	3.9	4.6	7.0	5.3	3.4	4.1	2.8	2.4
NNW	3.4	6.5	5.2	8.0	8.1	8.8	6.0	6.1	4.5	3.8	3.7	3.5
Variable	1.0	2.8	3.0	5.6	7.4	3.2	4.1	1.3	1.9	0.3	0.8	0.5
Calm	27.1	29.2	18.6	16.6	12.0	16.8	16.6	25.3	27.2	32.5	18.5	20.1

TABLE 60. Frequency (percent) of Winds as a Function of Direction at Fulda for 1200-1400 CET During 1973-1981

Direction	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
North	2.7	5.0	4.7	8.2	4.7	7.9	6.4	6.1	4.8	4.3	4.8	1.6
NNE	4.1	6.7	6.1	6.5	6.1	5.2	4.2	4.6	3.8	3.0	2.7	2.9
NE	1.6	2.9	5.3	7.3	4.0	6.0	2.2	3.6	3.1	1.7	2.3	1.6
ENE	0.3	2.5	2.2	5.8	7.0	3.0	1.9	5.7	2.5	2.2	0.3	1.1
East	0.9	1.2	1.5	3.3	4.3	3.0	1.9	3.4	1.6	1.6	1.0	0.5
ESE	1.1	2.5	1.0	2.7	2.3	2.7	2.6	3.2	0.8	2.2	0.8	0.3
SE	0.8	1.7	1.6	2.7	3.7	2.5	0.9	1.7	1.5	2.2	0.8	1.1
SSE	2.5	2.2	3.4	3.0	3.3	1.3	2.0	3.1	3.5	1.7	3.2	1.8
South	14.4	10.9	7.1	2.8	7.6	3.6	3.9	8.4	10.5	12.3	9.0	11.3
SSW	12.7	10.6	11.1	5.7	8.7	7.4	7.1	9.2	14.5	16.0	15.4	14.2
SW	10.5	8.2	8.1	5.8	6.7	5.7	8.7	7.5	10.5	9.5	16.4	14.4
WSW	8.9	6.7	11.1	8.8	5.9	8.1	10.7	8.4	8.2	7.5	11.0	13.3
West	8.0	5.4	8.6	5.8	7.3	9.4	14.1	5.8	8.9	6.8	12.0	8.4
WNW	1.9	1.8	4.3	3.9	3.7	7.3	7.3	3.5	4.6	4.7	3.7	2.6
NW	3.5	3.4	4.9	6.3	3.4	4.3	8.4	7.4	2.0	3.1	2.3	3.7
NNW	3.6	5.9	5.9	7.3	5.7	7.0	6.7	5.5	6.4	4.2	2.2	2.8
Variable	1.4	2.3	6.2	9.0	9.9	9.8	6.8	8.3	5.4	1.7	2.0	1.0
Calm	21.0	20.1	6.7	4.9	5.6	5.7	4.3	4.6	7.2	15.8	10.1	17.3

TABLE 61. Frequency (percent) of Winds as a Function of Direction at Fulda for 1500-1700 CET During 1973-1981

Direction	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
North	2.2	3.2	5.5	7.4	6.3	6.7	7.1	6.0	5.2	2.9	3.3	1.7
NNE	3.3	10.5	8.8	7.0	5.8	6.7	3.2	6.7	3.5	4.2	2.9	3.8
NE	2.6	7.3	5.5	8.9	4.5	6.5	3.0	4.8	3.2	2.0	3.3	1.3
ENE	0.5	1.4	2.6	5.8	6.7	4.5	2.8	4.6	2.4	2.9	0.6	0.9
East	0.9	1.2	1.0	3.0	2.8	3.3	1.5	5.0	1.5	0.7	0.4	0.2
ESE	1.1	3.0	1.2	2.1	3.7	1.7	2.8	4.1	0.7	1.6	0.4	0.6
SE	2.2	1.6	2.4	2.3	3.7	0.7	0.8	2.4	0.9	3.4	0.4	0.8
SSE	3.1	3.4	2.9	2.5	5.0	2.0	1.9	2.6	2.4	3.8	3.5	2.4
South	17.6	9.7	8.6	2.5	5.6	3.3	2.8	5.8	11.5	13.4	9.4	10.5
SSW	13.0	10.7	7.7	4.5	7.8	7.1	4.7	8.6	11.4	13.2	16.7	16.1
SW	10.6	12.7	10.3	6.8	5.2	5.9	7.9	7.7	13.2	11.2	14.5	15.9
WSW	9.0	6.0	11.7	8.7	7.8	9.3	13.9	6.2	10.8	8.9	9.6	11.6
West	9.2	5.6	8.1	7.2	9.7	10.0	13.7	7.2	7.8	6.3	11.0	8.1
WNW	2.2	2.8	4.5	5.5	4.8	8.4	9.0	6.2	6.5	5.6	4.5	3.2
NW	4.6	2.8	3.4	5.5	4.8	6.1	9.2	7.2	3.4	3.8	2.0	2.8
NNW	2.9	3.8	5.2	7.5	5.2	5.4	6.4	6.0	4.3	4.5	2.2	2.3
Variable	0.7	1.0	4.1	7.2	7.2	6.5	4.1	6.4	3.2	0.9	1.8	0.9
Calm	14.3	13.5	6.4	5.8	3.3	5.8	5.1	2.4	8.0	10.7	13.5	16.9

March through September. The frequency of variable winds is near 10 percent in the early afternoon in late spring and early summer. Variable winds are infrequent in early morning throughout the year and in winter throughout the day. Winds with westerly components are more frequent than winds with easterly components throughout the day and throughout the year. This is not surprising because Fulda is located within the middle latitude westerlies.

The direction from which winds blow most frequently does not usually coincide with the direction which has the highest mean speed. The highest frequency of occurrence is often at an angle rotated counterclockwise from the direction with the highest speed. Mean speeds are highest with W or WSW winds throughout the day during colder months, but the directions from which the wind is most likely to blow are SW, SSW, and S. A similar rotation may occur during the warmer months, but this does not happen consistently. Speed and frequency distributions are bimodal or multimodal. In spring and fall, relatively high mean speeds typically are associated with directions of ENE or NE and relative maximum frequencies of occurrence are from NNE and north.

2. Neighboring Areas

Regional surface layer wind fields in the Main-Taunus region just west of Fulda have been studied by Heimann [23]. The actual wind in this region deviates from the geostrophic wind more than a small deflection caused by friction. Channeling effects and thermally induced circulations are very important in the Main-Taunus region. For example, SSW and NNE winds prevail within a strip approximately 20 km wide along the Taunus mountains even though the most frequent directions of the geostrophic wind are WNW and SE. Thermally generated nocturnal downslope winds influence a larger area of the region.

The surface geostrophic wind shows negligible variation over distances of several tens of kilometers in the area around Fulda, but actual surface winds vary considerably. For example, Manier and Dietzer [24] compared frequency distributions of direction of geostrophic wind and of actual wind at numerous stations in the Federal Republic of Germany. Frequencies of direction of actual winds at the two stations are very different in two categories. The category 170°-200° contains 22 percent of winds at Kassel and 3 percent at Bad Hersfeld. The category 250°-280° contains 6 percent of winds at Kassel and 22 percent at Bad Hersfeld. These differences are consistent with the fact that the valley at Kassel runs S-N while the valley at Bad Hersfeld runs approximately SW-NE. Frequencies of actual and geostrophic wind directions are more closely related to each other on the mountain Kleiner Feldberg than at other stations in the region.

Winds within 100 km of Fulda are calm much of the time except on mountains [24]. Calms exist only 1 percent of the time on Kleiner Feldberg. Bad Hersfeld has calm winds 12 percent of the time. Calms are present at Coburg 14 percent of the time. At Giessen and Frankfurt am Main, 15 percent of wind measurements are calm. Calms exist 20 percent of the time at Würzburg and 21 percent at Kassel.

Koch [25] has examined thermally induced winds in a much earlier study. Koch discussed a few individual cases and quoted some climatic statistics. Winds at Meiningen about 50 km east of Fulda are from the southwest 29.9 percent of the time, from the south 11.0 percent, and from the west 9.3 percent where directions are measured to the nearest of 8 points of the compass. The corresponding numbers for Erfurt are 39.4 percent from southwest, 8.9 percent from south, and 13.3 percent from west.

3. Speed and Other Elements

Relationships of wind with other meteorological variables can be complex. For example, increased urbanization has caused mean speeds to decrease in many metropolitan areas while mean speeds in fog show no comparable decrease and may even increase [26]. During the winters 1946-47 through 1976-77, speed of wind during fog at Frankfurt am Main had no trend while overall mean speed decreased at the rate -0.0278 m/sec per year. During the years 1946 through 1976 at Frankfurt in fall, there was a small positive trend of speed during fog and a negative trend during all visibilities combined.

Lamp's [27] study of visibility and wind during the years 1949-1967 in Germany includes Frankfurt am Main. The correlation between the number of visibility observations below 800 m without heavy precipitation and the number of wind observations with speeds below 5 knots (2.6 m/s) is 0.16 at Frankfurt. This small positive correlation is lower than correlations for most of the other stations in the study. Lamp's investigation also included 5-year running means centered at the years 1951-1965. Correlation of the 5-year mean number of visibility observations below 800 m without heavy precipitation and the number of speeds below 5 knots is -0.46 at Frankfurt. The curve based on 5-year running means is smoothed compared to the curve based on individual years. During the period from 1949 through 1967 the average number of visibilities below 800 m decreased and the average number of winds with speeds below 5 knots increased at Frankfurt. This kind of trend is consistent with Stewart's [26] study.

Relationship of wind and temperature during the months of May in the years 1822-1897 has been investigated by Schubert [28]. Two locations from the study are near Fulda. Friedrichsrode is almost 70 km northeast of Fulda. Sonneberg is a little more than 100 km in a direction slightly south and east from Fulda. At both locations cooling at night was greatest with calm air and least with strong winds as expected. Furthermore, the effect was greater on a free thermometer than on a thermometer in an instrument shelter. Schubert did not make clear the boundaries on the wind categories, and so numerical values cannot be given here.

B. Vertical Variation

The station with upper air observations nearest to Fulda is Meiningen in the German Democratic Republic. Information for this station was obtained from Dr. Patrick Breitling, Chief Scientist of the Environmental Technical Application Center (ETAC) at Scott Air Force Base, Illinois. Profiles of monthly mean speeds from the surface to 10,000 ft (3048 m) at Meiningen are shown in Figures 7 through 18. The graphs also contain three additional profiles which consist of the mean plus one, two, and three standard deviations.

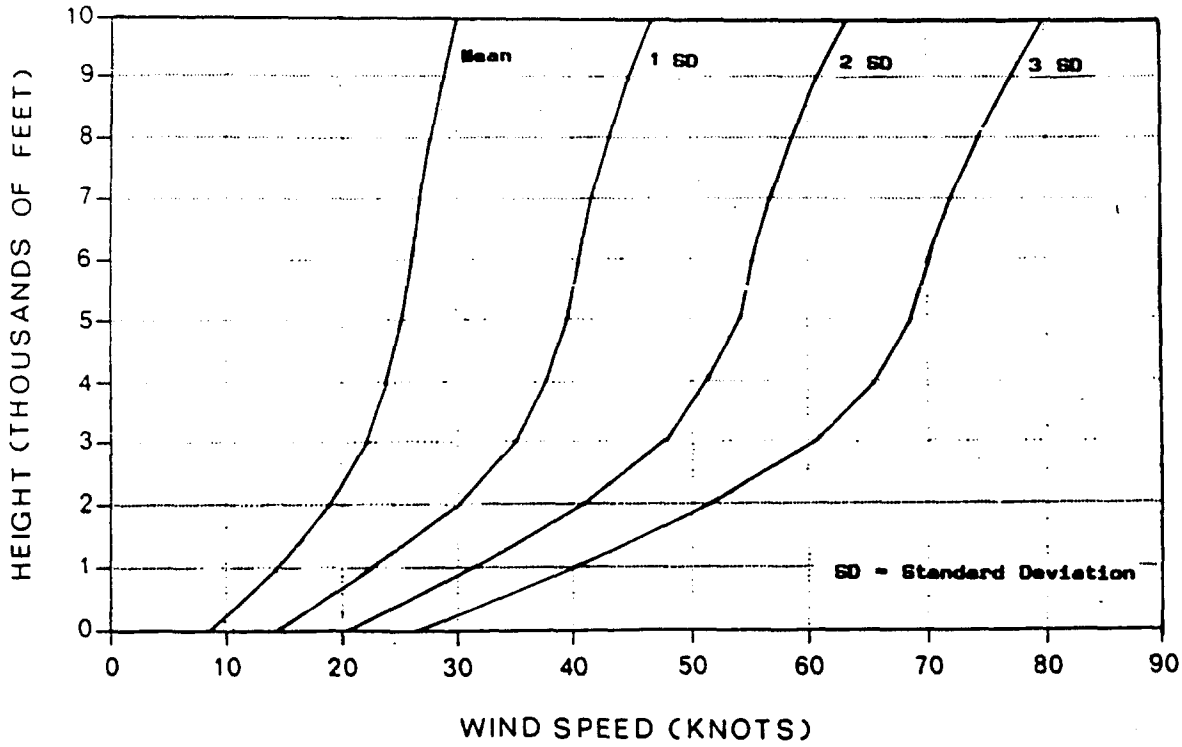

Figure 7. Speed of wind during January in the lowest 10,000 ft (3048 m) at Meiningen, German Democratic Republic.

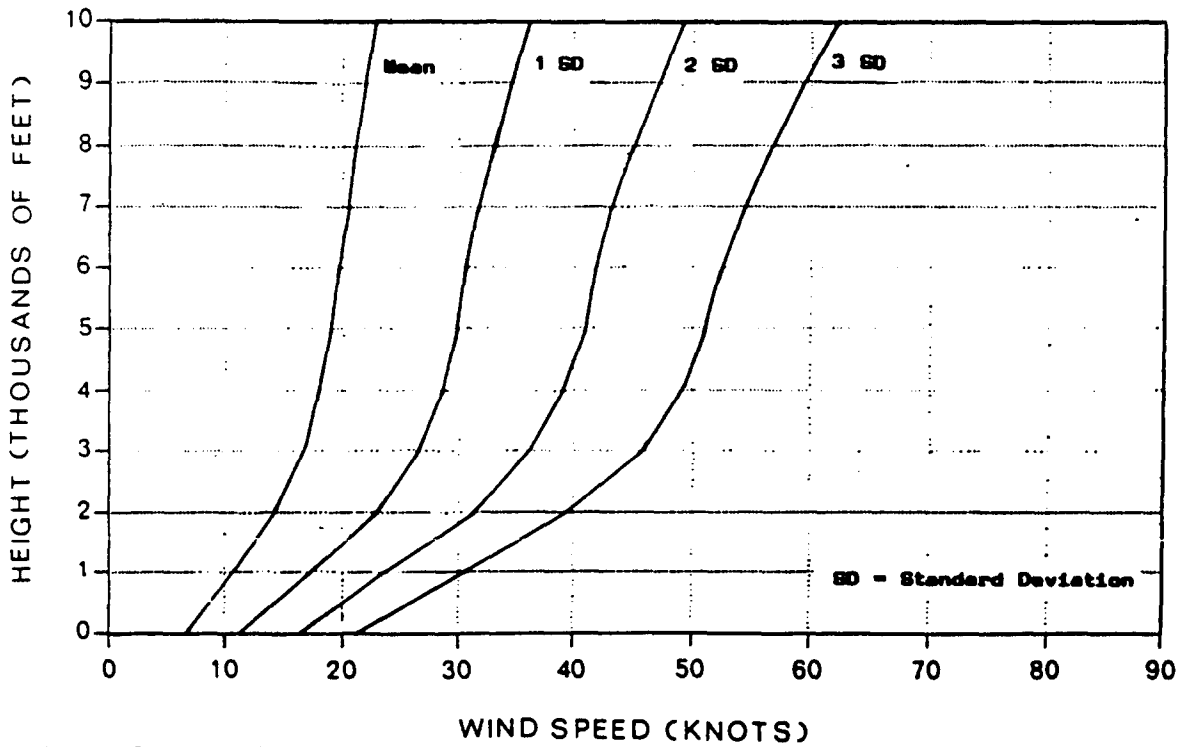

Figure 8. Speed of wind during February in the lowest 10,000 ft (3048 m) at Meiningen, German Democratic Republic.

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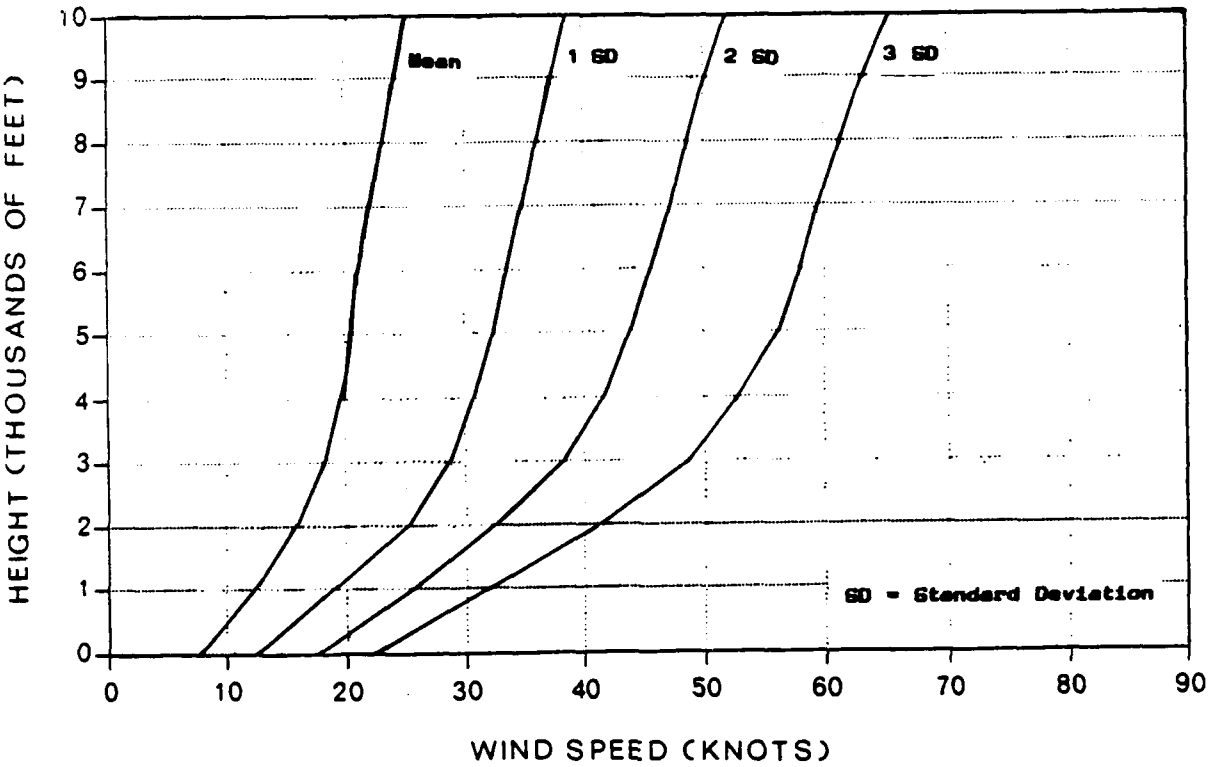

Figure 9. Speed of wind during March in the lowest 10,000 ft (3048 m) at Meiningen, German Democratic Republic.

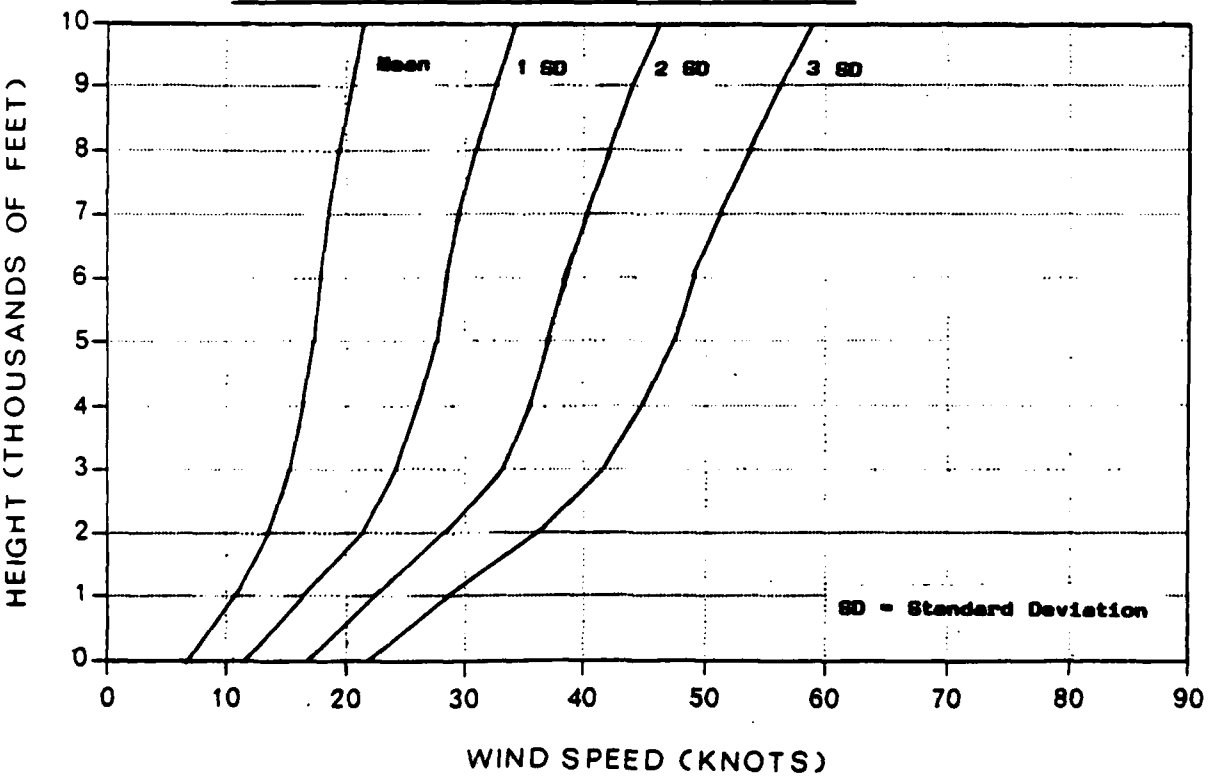

Figure 10. Speed of wind during April in the lowest 10,000 ft (3048 m) at Meiningen, German Democratic Republic.

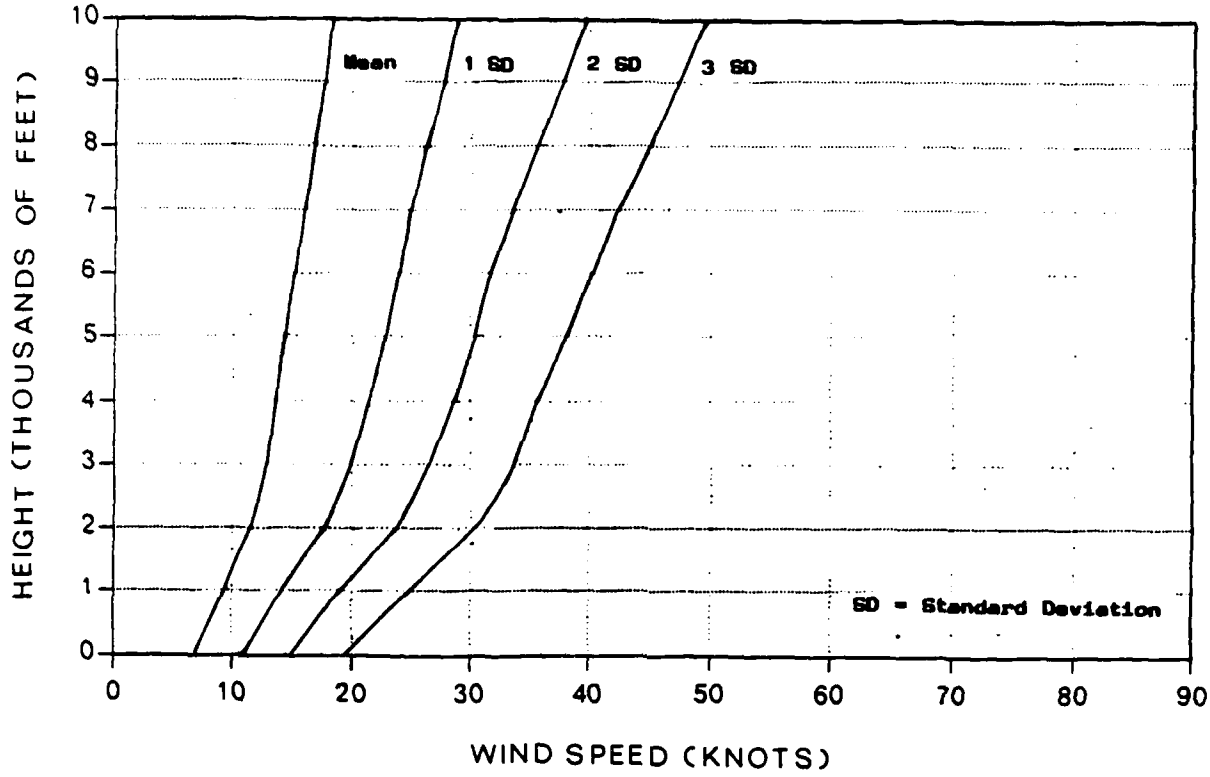

Figure 11. Speed of wind during May in the lowest 10,000 ft (3048 m) at Meiningen, German Democratic Republic.

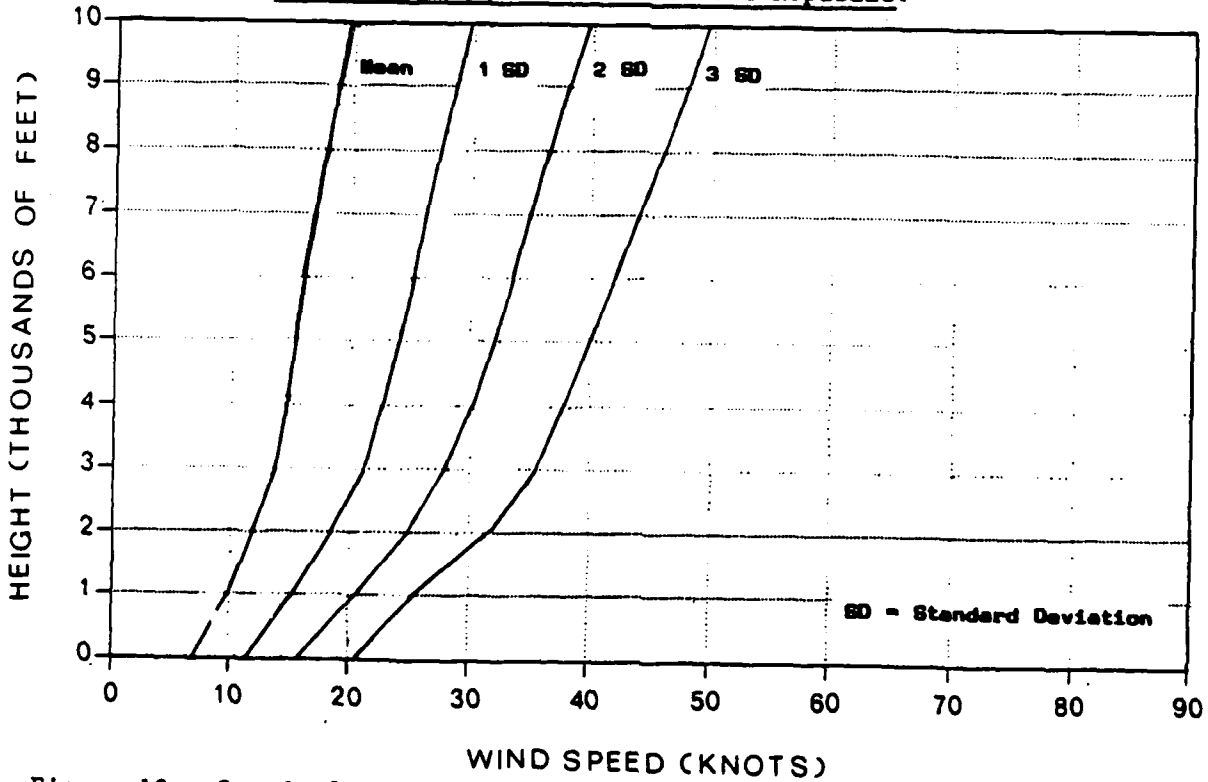

Figure 12. Speed of wind during June in the lowest 10,000 ft (3048 m) at Meiningen, German Democratic Republic.

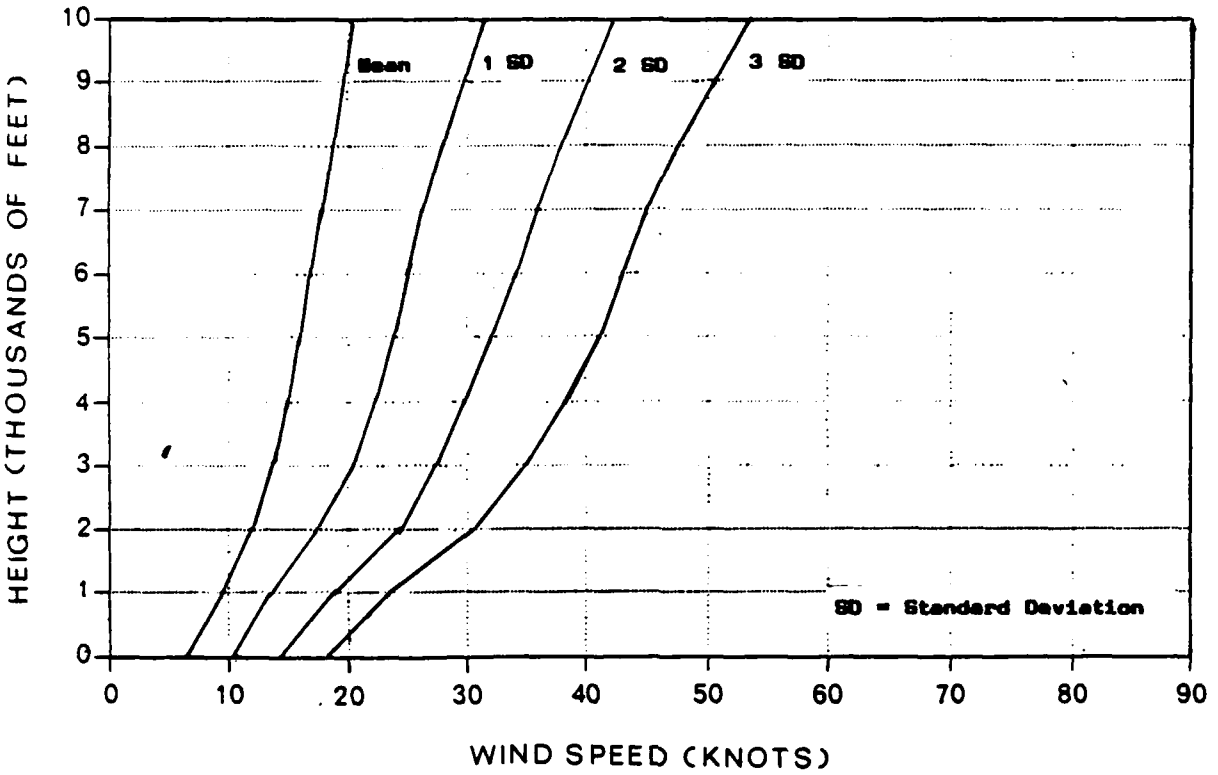

Figure 13. Speed of wind during July in the lowest 10,000 ft (3048 m) at Meiningen, German Democratic Republic.

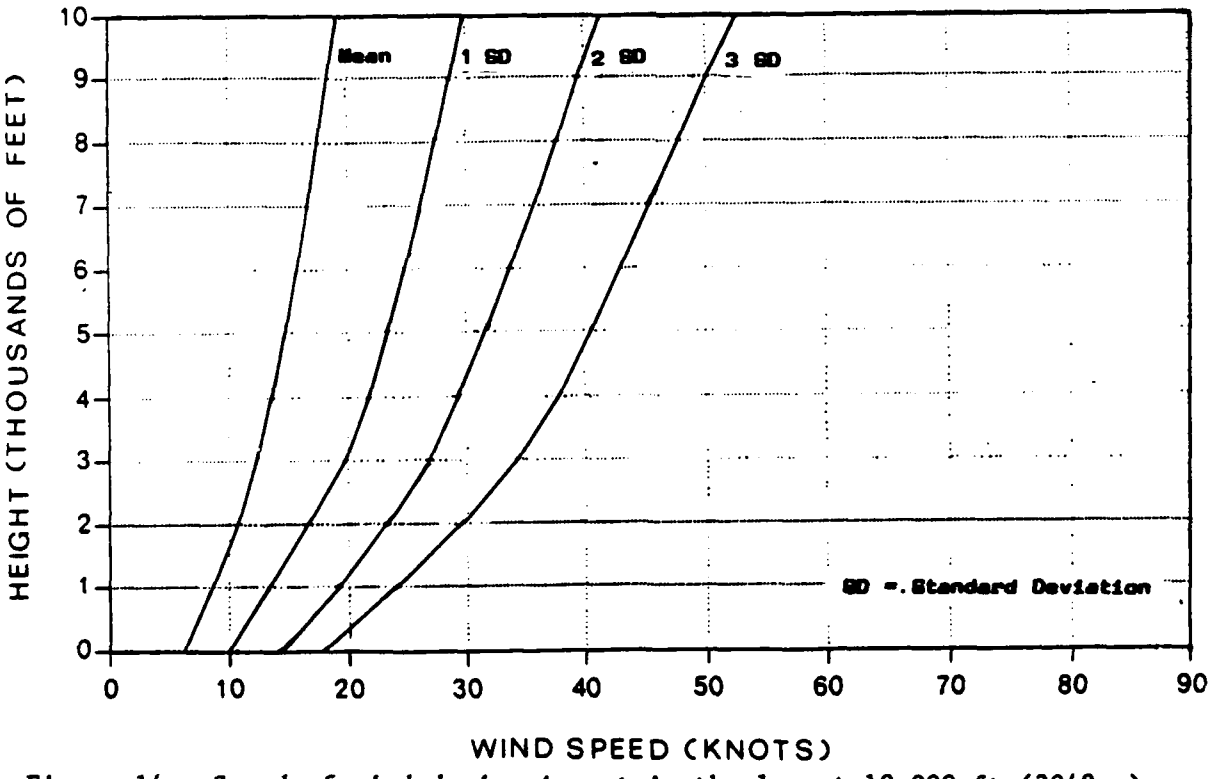

Figure 14. Speed of wind during August in the lowest 10,000 ft (3048 m) at Meiningen, German Democratic Republic.

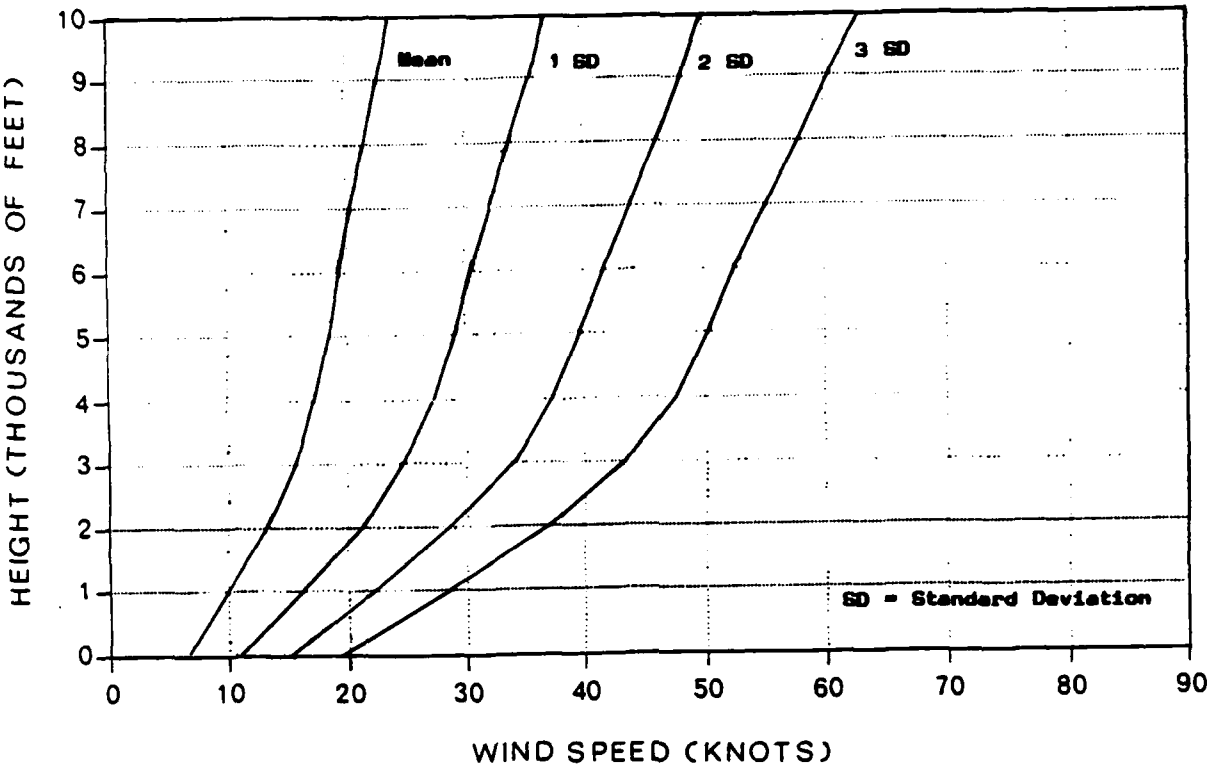

Figure 15. Speed of wind during September in the lowest 10,000 ft (3048 m) at Meiningen, German Democratic Republic.

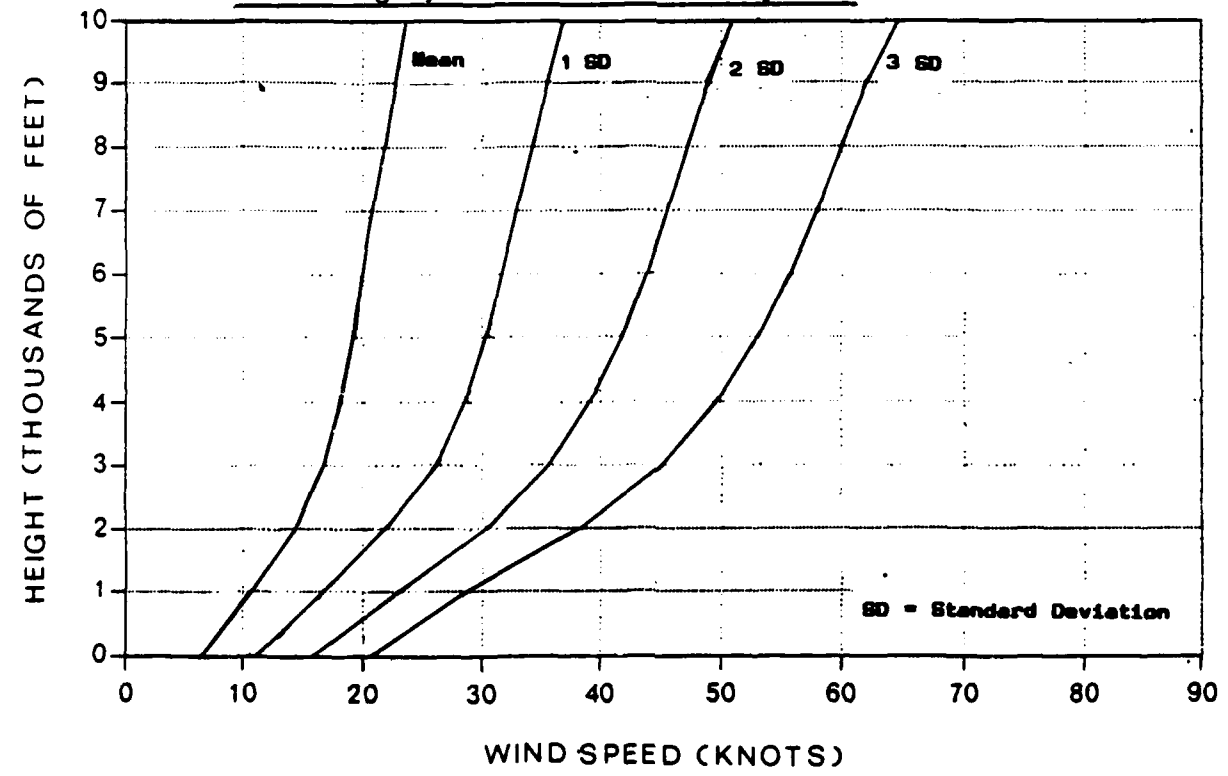

Figure 16. Speed of wind during October in the lowest 10,000 ft (3048 m) at Meiningen, German Democratic Republic.

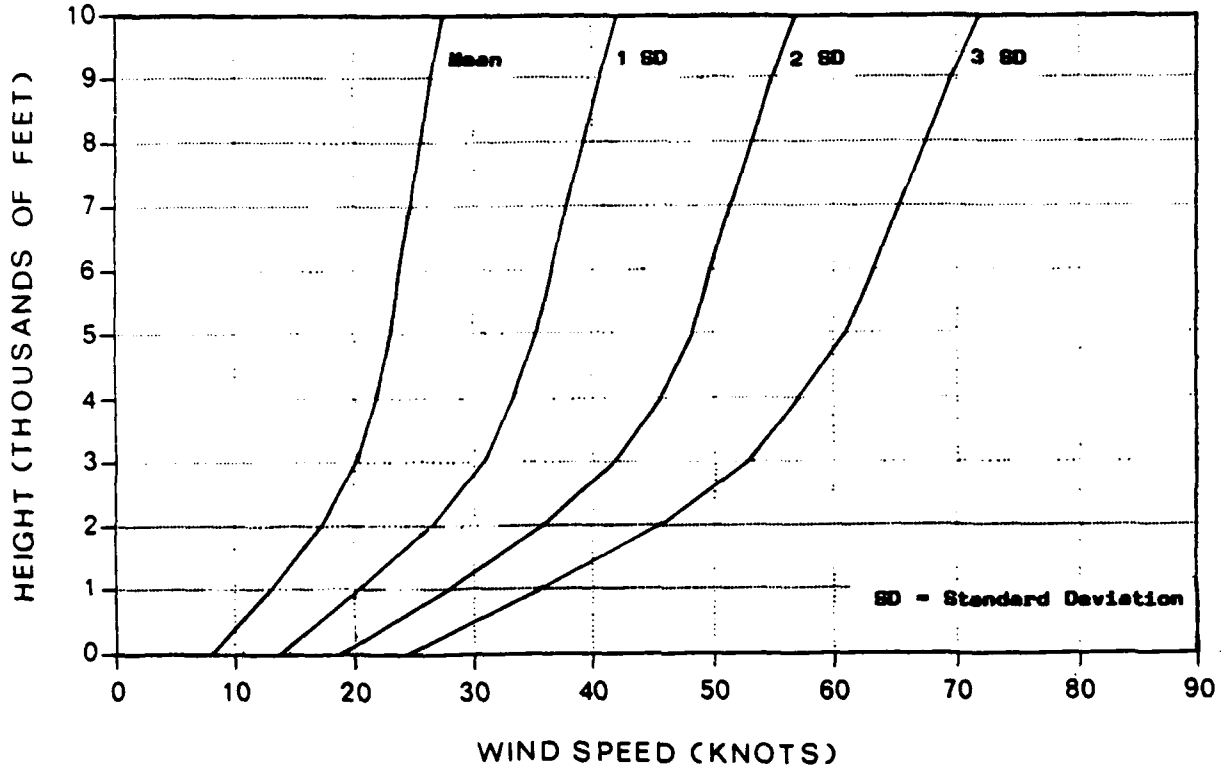

Figure 17. Speed of wind during November in the lowest 10,000 ft (3048 m) at Meiningen, German Democratic Republic.

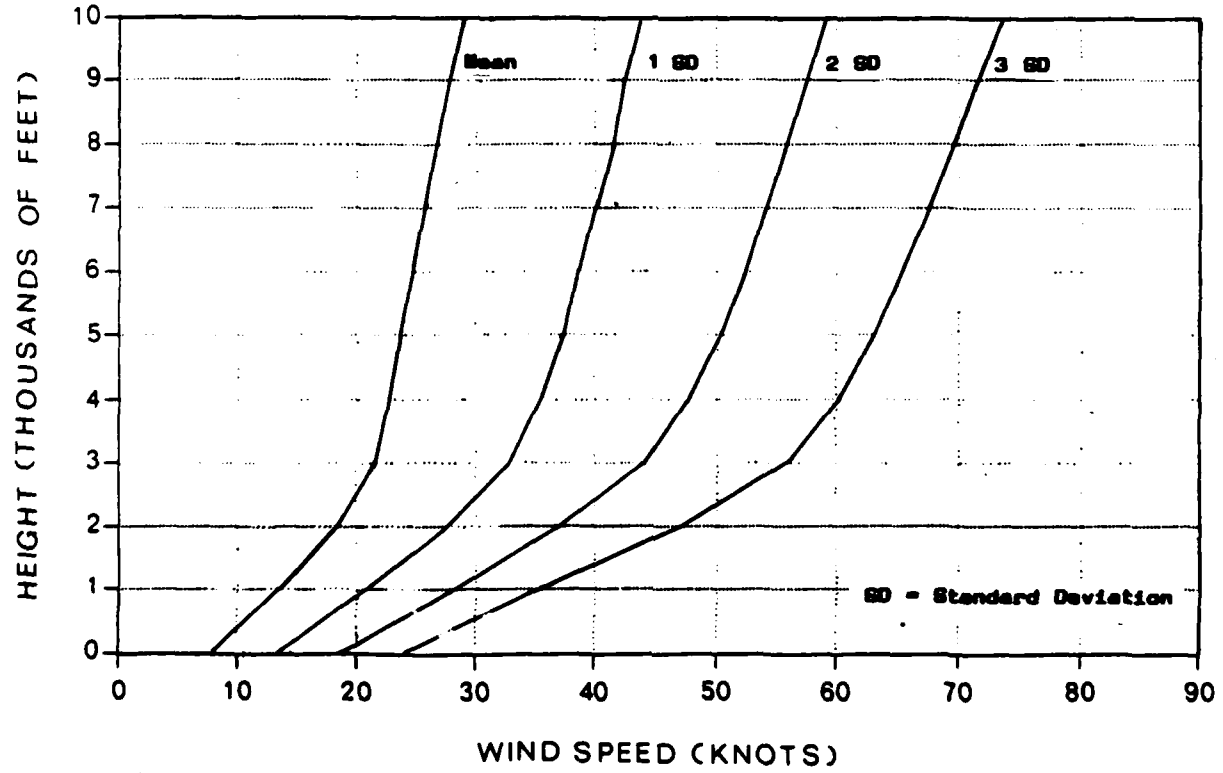

Figure 18. Speed of wind during December in the lowest 10,000 ft (3048 m) at Meiningen, German Democratic Republic.

Considerable variation occurs during the year at Meiningen. Monthly mean speeds in the lower layer are highest in January when they increase from 9 knots (4.6 m/s) at the surface to 30 knots (15.4 m/s) at 10,000 ft. The profile of December means is displaced from the January profile by approximately 1 knot (0.5 m/s) toward smaller speeds. Profiles for May and August are very close to each other with means near 19 knots (9.8 m/s) at 10,000 ft. Mean speeds in June and July are slightly higher than those in May and August.

Standard deviations of speed in the lowest 10,000 ft at Meiningen are largest in January and smaller in the warmer months. The mean plus three standard deviations at 10,000 ft is 80 knots (41.2 m/s) in January and slightly less than 50 knots (25.7 m/s) in May and June.

V. RELATIVE HUMIDITY

Table 62 lists monthly mean relative humidities for three-hourly periods during the daytime at Fulda. Each month follows the normal diurnal pattern with much lower relative humidities in the afternoon than near sunrise. Diurnal range is largest in August when 88.7 percent is the mean for 0600-0800 CET and 58.0 percent is the mean for 1500-1700 CET. From April through September the monthly diurnal range of relative humidity does not fall below 23 percentage points. The diurnal range is smallest in December when 90.8 percent is the mean relative humidity for 0600-0800 CET and 85.6 percent is the mean for 1200-1400 CET.

The seasonal range of monthly mean relative humidity at Fulda is much smaller near sunrise than in the afternoon. Monthly means for the 0600-0800 CET period range from 81.6 percent in May to 91.8 percent in February. Monthly means for 1500-1700 CET range from 57.7 percent in May and July to 86.1 percent in December.

Standard deviations of relative humidity for Fulda in Table 62 are in the range 7-18 percentage points. The diurnal change of standard deviation is smallest in January when the lowest and highest are 7.5 percentage points at 0600-0800 CET and 9.1 percentage points at 1200-1400 CET. The diurnal change is largest in August when the lowest and highest standard deviations of relative humidity at Fulda are 9.1 percentage points at 0600-0800 CET and 17.2 percentage points at 1500-1700 CET. The largest standard deviation in Table 62 is 18.2 percentage points at 1500-1700 CET in May.

TABLE 62. Relative Humidity at Fulda from the Revised Uniform Summary of Surface Weather Observations for 1973-1981

Element* / Time (CET)	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
RH												
06-08	91.2	91.8	88.6	84.9	81.8	84.2	84.9	88.7	90.8	91.0	88.1	90.8
09-11	89.5	89.4	82.8	73.3	67.3	69.7	71.2	73.3	79.4	84.4	85.5	89.2
12-14	85.7	82.9	73.1	62.8	59.1	60.8	61.2	61.8	67.1	74.5	80.6	85.6
15-17	86.5	80.4	71.2	60.0	57.7	58.3	57.7	58.0	64.8	73.6	81.8	86.1
σ(RH)												
06-08	7.5	7.6	9.1	10.5	11.2	9.8	10.0	9.1	8.7	8.9	8.2	7.3
09-11	8.2	8.7	11.1	15.0	16.1	13.6	14.4	14.6	12.3	12.2	10.2	7.7
12-14	9.1	12.8	13.9	17.2	17.0	15.6	16.0	16.8	13.8	14.1	10.5	9.6
15-17	8.7	14.2	15.7	17.8	18.2	16.3	16.8	17.2	14.6	14.6	9.8	9.3

*RH = Relative Humidity in Percent
σ(RH) = Standard Deviation of Relative Humidity in Percent

VI. SUMMARY

Fulda is in Central Europe in the Central Mountains of the Federal Republic of Germany. This region has a temperate climate and has no dry season. Minimum temperatures at Fulda are below the freezing point of water on approximately half the days in January. Maxima in July are above 80 °F approximately 15 percent of the days. About 50 percent more rain falls at Fulda during the three summer months than during the three winter months.

Low visibilities and low ceilings are more common in fall and winter than in spring and summer. Low visibilities are more frequent in the early morning than in the afternoon throughout the year. Early morning fog is much more frequent in fall than in winter. Afternoon fogs are more likely to occur in winter than in fall.

The location of Fulda in the middle latitude westerlies influences its wind patterns. Winds which blow from directions with westerly components are more frequent than winds with easterly components throughout the day and throughout the year. The diurnal variation of speed is large in all seasons except in winter. The largest diurnal variation at Fulda is in August when the mean speed is 1.7 knots for 0600-0800 CET and 6.4 knots for 1500-1700 CET. Calms occur more frequently in the morning than in the afternoon throughout the year.

All meteorological variables can change rapidly over relatively small distances around Fulda because of the mountainous terrain.

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